

Robert Miner Dynamic Testing, Inc.

Dynamic Measurements and Analyses for Deep Foundations

December 17, 2021

Ilima Alexander
Flatiron-Lane JV
1400 Talbot Rd S. Ste. 500
Renton, WA 98055

I-405, Renton to Bellevue Widening & Express Toll Lanes Project

DOCUMENT REVIEW
 APPROVED, NO EXCEPTION TAKEN
 APPROVED AS NOTED
 RESUBMIT, REVISE AS NOTED

REVIEWED BY: Bon Lien DATE: 01/07/22
J. Broadus 1/7/22

Review is for general conformance with contract or design documents. Sole responsibility for correctness of dimensions, details, quantities, materials, and safety during fabrication and erection shall remain with the contractor.

Re: Wave Equation Analysis of Pile Driving
Pier 2: PP24"x0.50", Open-ended
APE D80-42 and APE D100-42 Open-end Diesel Hammer
WSDOT I-405 Renton to Bellevue Design-Build: Bridge 26E
Renton, Washington

RMDT Job No. 21F24

Ms. Alexander:

At your request, we performed wave equation analyses for the project referenced above. The objectives of these analyses were prediction of axial pile stresses and penetration resistances during pile driving. The following sections summarize data submitted to Robert Miner Dynamic Testing, Inc. (RMDT), program input, analyses made, results, and our opinions regarding certain aspects of pile driveability.

ANALYSIS DETAILS

Our analyses are primarily based on project documents you provided. These documents included Section 6-05 of the amended project specifications, Plan Sheets BG26E-01, 2, 4 and 5, a Geotechnical Engineering Report (March 09, 2021) prepared by Wood Environment & Infrastructure Solutions, Inc., the draft pile driving plan and the pile driving equipment data forms. Additional information incorporated into our analyses and discussion was taken from GRLWEAP™ program data files, or based on our judgment.

Program: GRLWEAP™, Version 2010

Pile Details: The proposed piles are vertical 24" OD open-ended steel pipe piles with a wall thickness of 0.50" and anticipated driven lengths of either 90 or 115ft. We understand that all steel pile material has a minimum yield strength, Fy, of 50 ksi.

Soil and

Foundation

Design: Subsurface conditions at the site are reported to consist of approximately 50 ft of medium dense silts and clay underlain by dense to very dense silty sands, gravels and clay. The foundation design anticipates all piles will achieve end bearing in the lower dense silty sands, gravels and clay.

We understand that all Pier 2 piles will be driven through approximately 20 to 30 ft of overburden material. Information contained on Plan Sheet BG26E-05 for Pier 2 indicates a minimum tip elevation of -13 ft and an estimated pile tip elevation of -53 ft. Pier 2 North Piling are to be installed as 115 ft long pile sections. Pier 2 South Piling will be installed initially as 90 ft long pile sections, if necessary, an additional 25 ft pile section will be field spliced yielding a final driven pile length of 115ft. After all pile installation is complete the overburden material will be excavated to an elevation of +27.8 ft and piles will be cut-off at an elevation of +29.8ft.

Note 2 on the Plan Sheet BR26E-05 states that nominal pile driving resistance during pile driving shall be the sum of 1030 kips and the pile dead weight. RMDT has estimated the dead weight, inclusive of interior soil, to be 40 kips. We estimate 60 kips of temporary shaft resistance may conservatively be assigned to the upper 20 to 30 ft of overburden material during initial pile advancement. Therefore, we have taken the 1130 kip sum of these quantities as the required maximum driving resistance (RNDR) for purposes of hammer evaluation and hammer approval.

Select pile design details provided on Plan Sheet BG26E-05 and the dead weight calculated by RMDT are summarized in Table 1. For further information on the soils and foundation design please refer to appropriate project documents.

Table 1: Selected Details for PP24"x0.50" Pier 2 Piles

Structure	Minimum Tip Elevation (ft)	Estimated Tip Elevation (ft)	Bottom of Pile Cap Elevation (ft)	Estimated Pile Tip Depth (ft)	Required Nominal Pile Driving Resistance ¹ (kips)
Pier 2	-13	-53	+28	81	1130

Note¹: Apparent nominal driving resistance is the sum of the 1030 kip required nominal bearing resistance, a 40 kip pile dead load calculated by RMDT and 60 kips of temporary shaft resistance associated with 20 to 30 ft of overburden material, as estimated by RMDT for application to hammer approval.

Hammers: At your request we considered both the APE D80-42 and D100-42 single-acting diesel hammers. Driving system parameter values are summarized in Table 2.

Table 2: Select Driving System Details					
Hammer	Maximum Rated Energy kip-ft	Ram Weight kips	Maximum Ram Stroke ft	Helmet Weight kips	Hammer Cushion Stiffness kip/inch
APE D80-42	198	17.6	11.3	8.5	39,981
APE D100-42	248	22.0	11.3	8.5	39,981

Analysis

Input:

Wave equation analyses were completed for 24" OD piles driven open-ended with an APE D80-42 and D100-42 hammer models. Analyses were completed for a 90 ft pile installed through 20 ft of overburden to a 61 ft tip depth (corresponding to a tip elevation of -13 ft) with the majority of ultimate resistance allocated to the pile toe. Analyses were also completed for a 115 ft pile installed through 30 ft of overburden to a 111 ft tip depth (corresponding to a tip elevation of -53 ft) with ultimate resistance split evenly between pile shaft and toe. Soil parameter values and related information applied to our wave equation analyses are summarized in Table 3.

Table 3: Select GRLWEAP Analysis Inputs		
Pile Length	90 ft	115 ft
Soil Penetration	61 ft	111 ft
Soil Quake (skin)	0.10 in	0.10 in
Soil Quake (toe)	0.20 in	0.20 in
Soil Damping (skin)	0.05 sec/ft	0.05 sec/ft
Soil Damping (toe)	0.15 sec/ft	0.15 sec/ft
% Shaft Friction (Triangular Resistance Distribution)	30%	50%

RMDT did not perform soil resistance calculations to compute any relation between soil resistance and length of pile penetration. Such static soil analyses were beyond the scope of this report. Total soil resistance primarily controls wave equation results with respect to driveability; reasonable variation of assumed total soil penetration or resistance distribution typically has only minor effects on these computed results.

Hammer Approval

Requirements:

The analyses presented here follow certain requirements of the 2018 Washington State Standard Specifications (6-05.3(9)A) under which the predicted penetration resistance must be less than 100 blows per ft for the required ultimate (nominal) resistance and the predicted pile stresses must be less than 90 percent of material yield strength.

Project documents do not appear to anticipate overdrive when driving to the required minimum tip elevation and we take the maximum driving resistance as RNDR with a value of 1130 kips, as given in Table 1. Per Specification (6-05.3(9)A) a setup factor 1.3 could be applied to the required driving resistance. However, we did not apply this portion of the specification as both proposed hammers are capable of overcoming the RNDR value.

Analysis

Type: We completed Bearing Graph format analyses with a range of soil resistance values and the two hammer efficiencies, 0.72 and 0.84 percent as called for in the Washington State Standard Specifications (6-05.3(9)A). Results for analyses with the lower and higher efficiencies are identified by "LO" and "HI" in the analysis title block. For each assigned axial soil resistance the GRLWEAP Bearing Graph results included predicted peak axial compressive stresses and penetration resistance (blows per ft).

For analyses of the APE D80-42 and D100-42 we set the hammer combustion pressure to 105 and 100-percent of the GRLWEAP default value, respectively. These combustion pressures likely reflect hammer operation at the maximum fuel setting and produce analyses with predicted stroke heights consistent with our expectations for stroke heights for this pile profile driven into dense to very dense soils.

GRLWEAP RESULTS

The GRLWEAP Bearing Graph Analyses provide values for penetration resistance (blows per ft) and driving stress for a wide range of assigned soil resistance values. Attached pages contain a graphic summary of results and a summary of key program inputs values. Additional pages provide numeric summaries of the analyses. Appendix A contains further input and results which may be used for more detailed review of the analyses we completed. Table 4 summarizes the results for the various cases considered at the required driving resistance of 1130 kips.

Table 4. Summary of GRLWEAP Results for the Required Resistance					
Hammer	Pile Length ft	Pile Penetration ft	Required Resistance kips	Penetration Resistance Blows/ft	Axial Compressive Driving Stress ksi
APE D80-42	115	111	1130	61 (LO)	33 (HI)
APE D80-42	90	61	1130	45 (LO)	43 (HI)
APE D100-42	115	111	1130	46 (LO)	36 (HI)
APE D100-42	90	61	1130	37 (LO)	44.8 (HI)

DISCUSSION

The following results and opinions are based on the information provided to us, the results of our analyses, and our engineering judgement. The discussion below summarizes analysis for the longer pile (115 ft) when considering penetration resistance, and the shorter pile (90 ft) when considering axial driving stress. Such summary presents values that are closest to the acceptable limits for penetration resistance and driving stress, respectively.

APE D80-42

1. GRLWEAP analyses for the 115 ft long pile with a hammer efficiency of 0.72 (LO) yielded a penetration resistance of approximately 61 BPF for a driving resistance of 1130 kips. The calculated ram stroke height corresponding to a resistance value of 1130 kips is 8.9 ft. In our opinion, hard driving should be expected with the APE D80-42 if driving resistances of 1250 kips or greater are encountered prior to reaching the minimum pile tip elevation.
2. GRLWEAP analyses for the 90 ft long pile with a hammer efficiency of 0.84 (HI) yielded a maximum computed axial compressive driving stress below 43 ksi for a driving resistance of 1130 kips with a calculated ram stroke height of 9.6 ft. This computed stress value is less than 90 percent of the reported 50 ksi pile material yield strength. The predicted axial compressive driving stress exceeded 47 ksi for the largest analyzed resistance of 1500 kips at a calculated ram stroke height 10.9 ft.

APE D100-42

3. GRLWEAP analyses for the 115ft long pile with a hammer efficiency of 0.72 (LO) yielded a penetration resistance of approximately 46 BPF for a driving resistance of 1130 kips. The calculated ram stroke height corresponding to a resistance value of 1130 kips is 8.7 ft. In our opinion, hard driving should be expected with the APE D100-42 if driving resistances of 1350 kips or greater are encountered prior to reaching the minimum pile tip elevation.

4. GRLWEAP analyses for the 90 ft long pile with a hammer efficiency of 0.84 (HI) yielded a maximum computed axial compressive driving stress below 45 ksi for a driving resistance of 1130 kips with a calculated ram stroke height of 9.2 ft. This computed stress value is less than 90 percent of the reported 50 ksi pile material yield strength. The predicted axial compressive driving stress was approximately 51 ksi for the largest analyzed resistance of 1600 kips at a calculated ram stroke height 10.5 ft.

APE D80-42 and APE D100-42

5. It is our opinion that the APE D80-42 and the APE D100-42 hammers each meet the specification requirements regarding hammer approval. Both hammers are expected to accommodate a modest degree of overdriving relative to the 1130 kip resistance which pertains to Pier 2.
6. The GRLWEAP computed driving stresses do not include any stresses that result from local contact or bending. Thus, total stresses may be higher than the GRLWEAP computed values. We recommend careful attention to preparation of the pile for driving and proper alignment of the hammer, helmet, striker plate, and pile during all driving.
7. The APE D80-42 and D100-42 hammers have a variable fuel supply that provides some control of the ram stroke height. We recommend stroke height not exceed 9 ft for either hammer model during initial pile installation. However, we also recommend that either hammer be operated at lower strokes if lower strokes suit the soil resistance during driving and efficiently achieve the required minimum tip elevation and depths at which pile acceptance criteria are satisfied.
8. We understand that dynamic pile testing with a Pile Driving Analyzer® and CAPWAP® signal matching methods will be applied to installation and restrike of Test Piles, and that such methods will be a basis for proposing production pile driving criteria for review by the geotechnical engineer. The GRLWEAP analyses presented and discussed herein address hammer approval under WSDOT specifications and should not be used as a basis for pile inspection or pile acceptance.

ADDITIONAL CONSIDERATIONS

Please note that the results calculated by the wave equation analysis program depend on a variety of hammer, pile and soil input parameters. Please also review the information that is given on the cover page for Appendix A. We attempted to base our analyses on our best interpretation of information provided to us for this work and to also consider the relation of uncertainty to our opinion about hammer suitability. However, actual field conditions, project requirements and hammer performance may vary from what we assumed and therefore driving stresses and blow counts may differ from these predictions. Soil setup during interruptions to driving, or soil conditions that cause actual resistance values to exceed the stated resistance

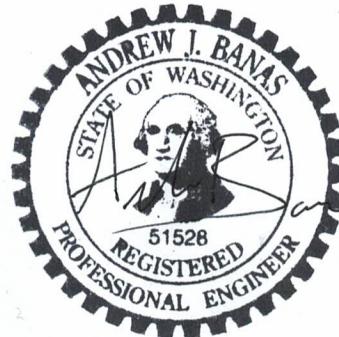
values may cause harder driving than is predicted in these analyses. RMDT did not evaluate or predict any relation between tip elevation and soil resistance or tip elevation and driving resistance. Soil resistance values assigned in wave equation analyses are ultimate resistance values.

We enjoyed performing these analyses for you. If you or your client have any questions or if we can provide further assistance, please contact us.

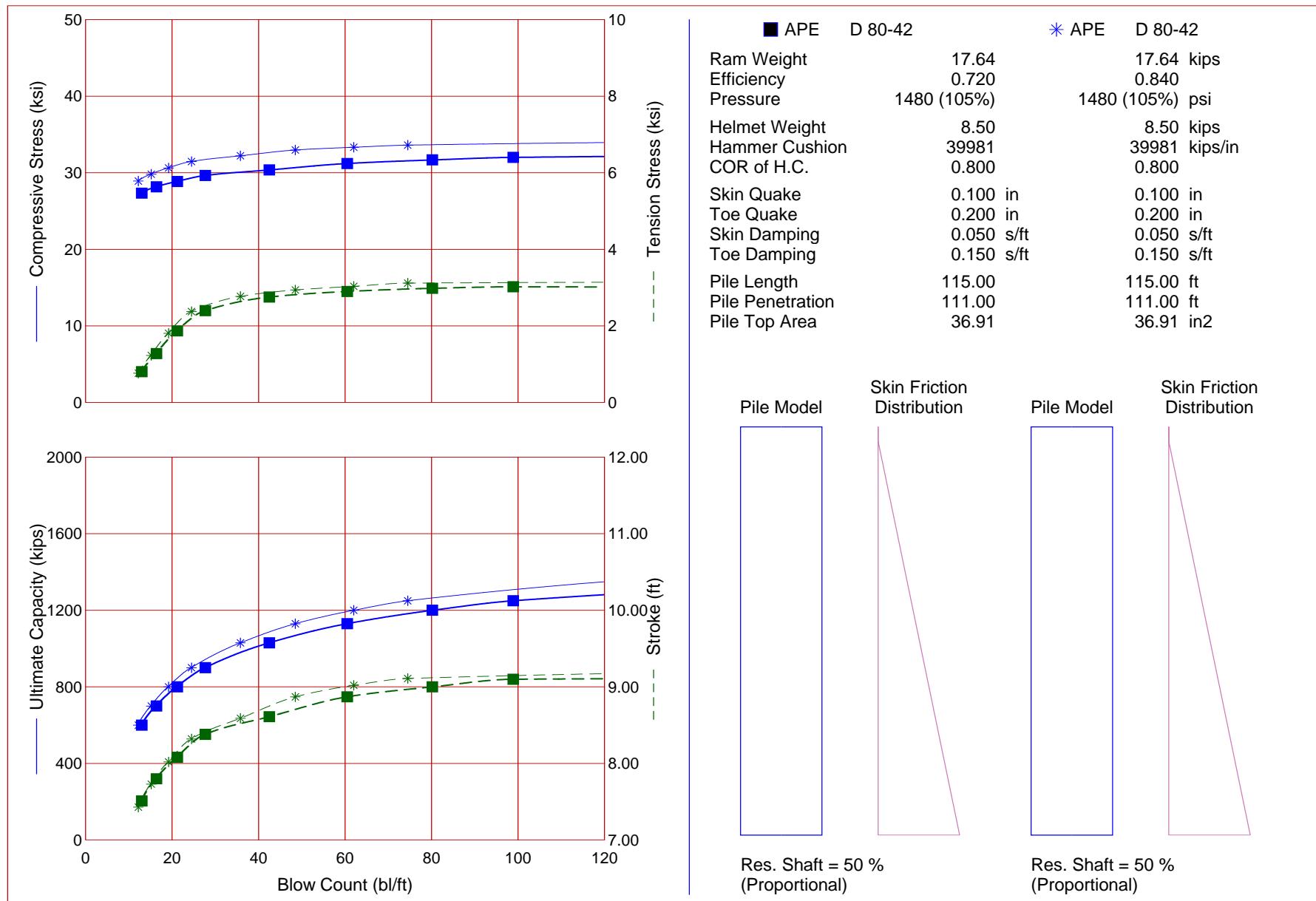
Sincerely,

Andrew J. Banas, P.E.

Robert Miner Dynamic Testing, Inc.



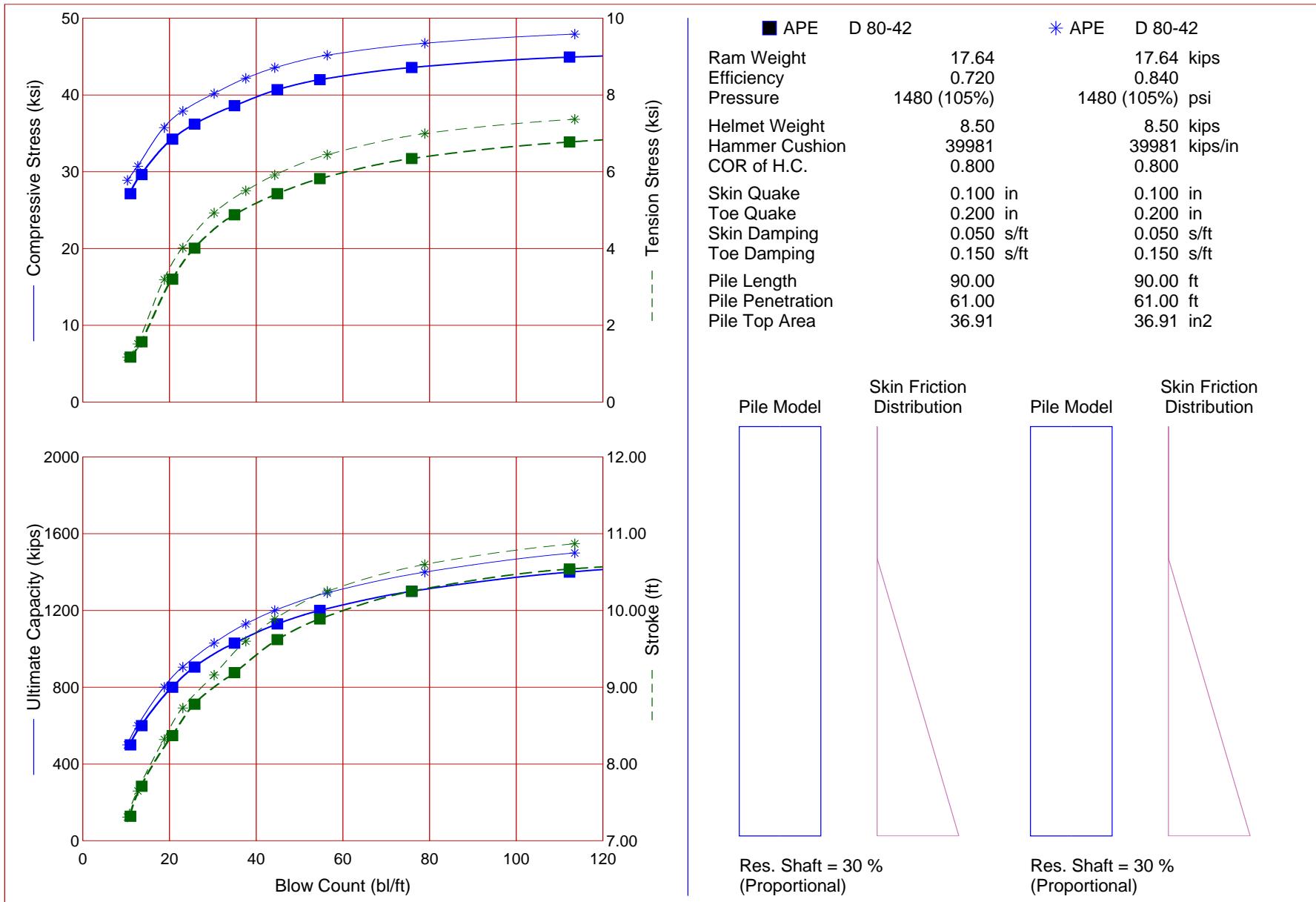
12/17/2021



Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count bl/ft	Stroke ft	Energy kips-ft
600.0	27.33	0.81	13.0	7.51	93.94
700.0	28.16	1.28	16.4	7.80	94.87
800.0	28.86	1.87	21.2	8.08	95.90
900.0	29.64	2.40	27.7	8.38	97.77
1030.0	30.36	2.75	42.5	8.61	99.61
1130.0	31.21	2.90	60.5	8.87	101.76
1200.0	31.67	2.98	80.2	9.00	102.68
1250.0	32.01	3.02	98.9	9.10	103.43
1400.0	32.54	3.01	236.7	9.13	102.72
1500.0	32.87	3.21	390.6	9.15	102.29

Flatiron, BR26P2, PP24x0.50, D80, 115ft, HI

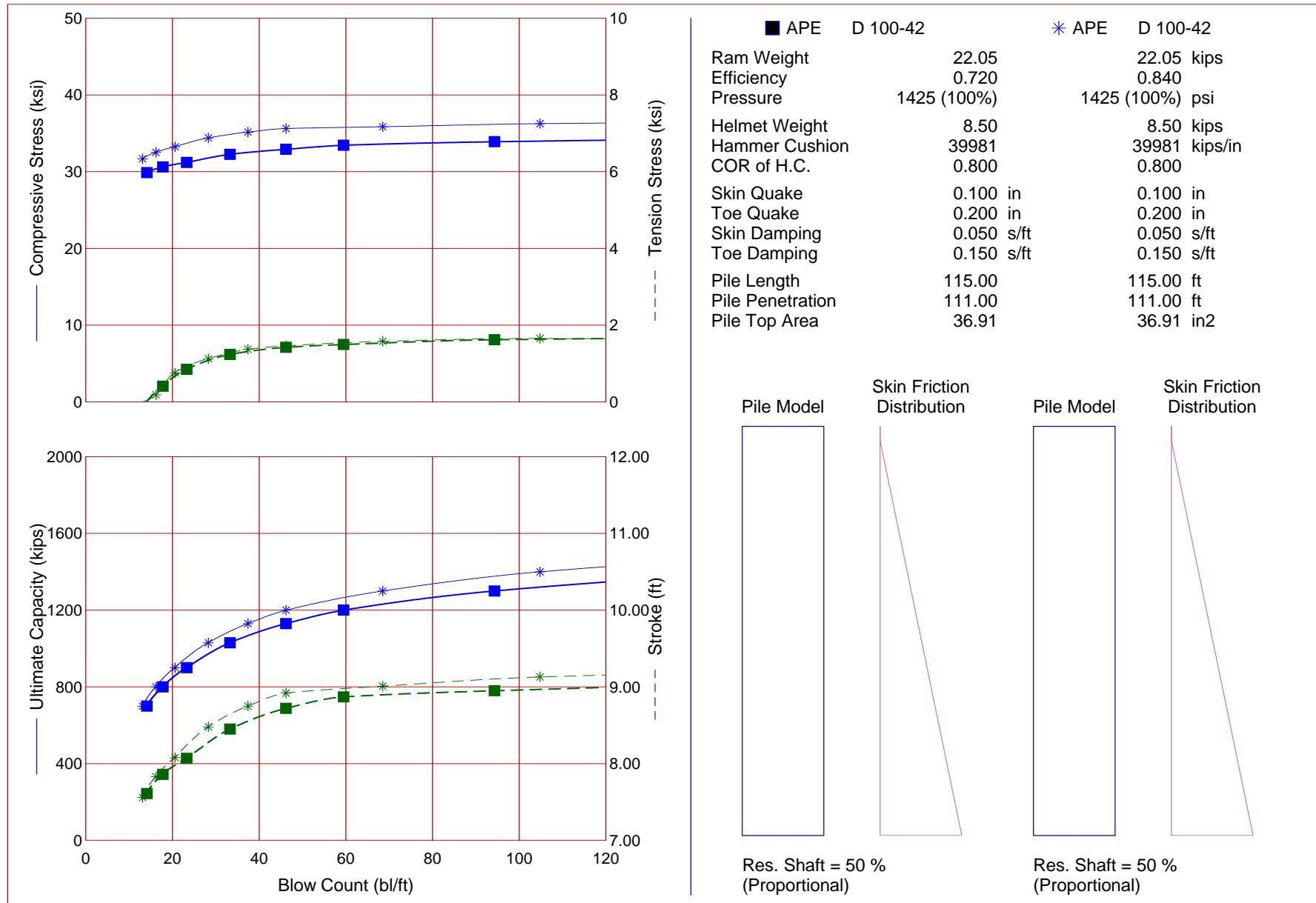
Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count bl/ft	Stroke ft	Energy kips-ft
600.0	28.92	0.77	12.2	7.43	101.19
700.0	29.81	1.23	15.2	7.73	102.50
800.0	30.63	1.81	19.2	8.02	104.12
900.0	31.47	2.38	24.5	8.32	106.35
1030.0	32.22	2.77	35.8	8.59	108.91
1130.0	32.97	2.94	48.5	8.87	111.69
1200.0	33.33	3.04	62.0	9.02	113.04
1250.0	33.61	3.12	74.5	9.11	113.87
1400.0	34.10	3.15	153.0	9.20	113.75
1500.0	34.45	3.17	254.4	9.24	113.57



Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count bl/ft	Stroke ft	Energy kips-ft
500.0	27.13	1.17	11.0	7.32	93.05
600.0	29.63	1.57	13.6	7.71	94.31
800.0	34.24	3.20	20.7	8.37	98.04
905.0	36.20	4.01	25.8	8.78	101.22
1030.0	38.59	4.88	35.0	9.19	104.15
1130.0	40.69	5.43	44.9	9.62	107.72
1200.0	41.98	5.82	54.7	9.89	110.06
1300.0	43.58	6.34	75.9	10.25	112.95
1400.0	44.92	6.78	112.3	10.54	115.43
1500.0	45.90	7.17	184.3	10.73	116.99

Flatiron, BR26P2, PP24"x0.50", D80, 90ft, HI

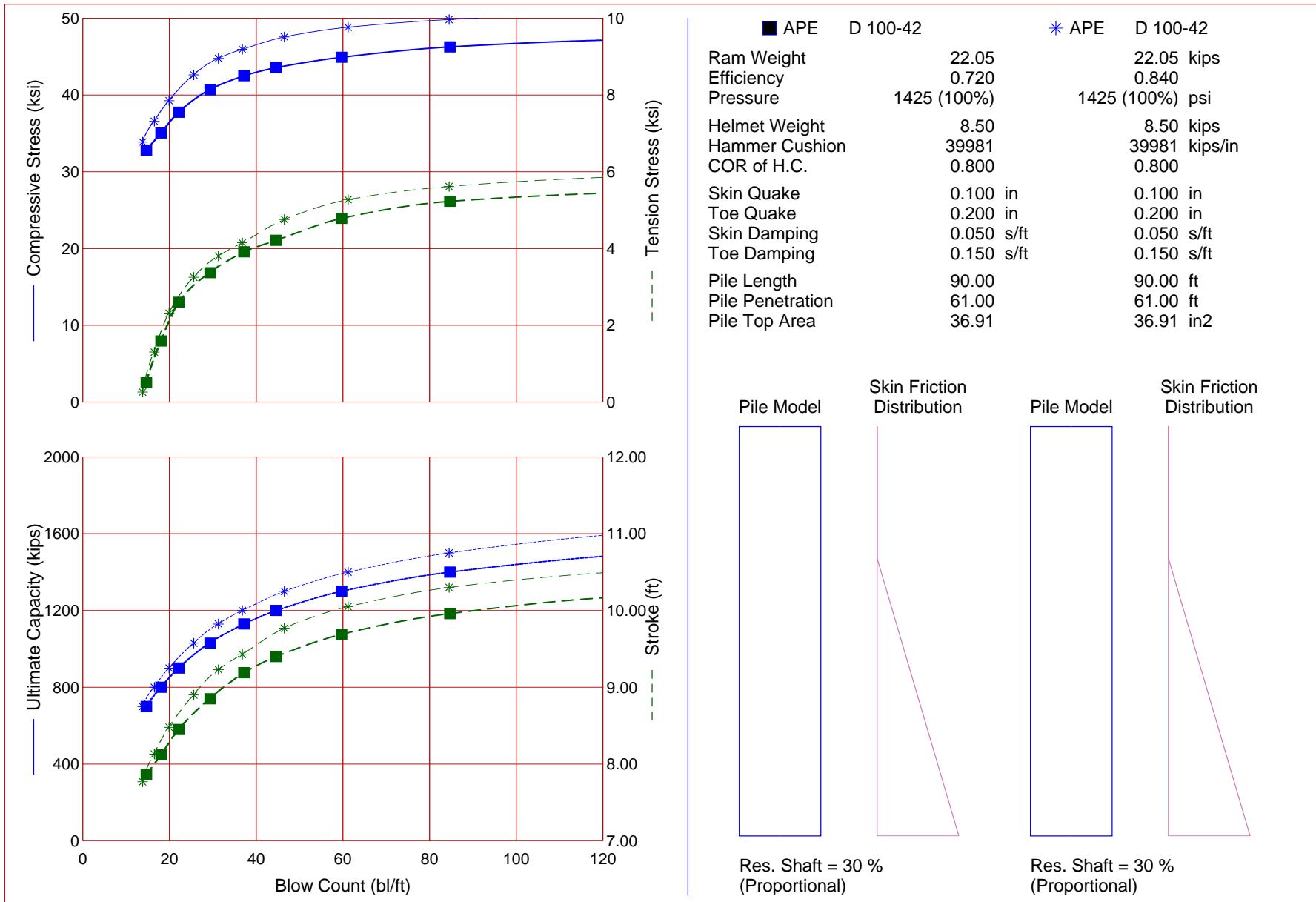
Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count bl/ft	Stroke ft	Energy kips-ft
500.0	28.89	1.17	10.3	7.31	101.19
600.0	30.72	1.52	12.7	7.65	102.08
800.0	35.75	3.19	18.8	8.32	106.70
905.0	37.89	4.02	23.1	8.73	110.40
1030.0	40.17	4.93	30.3	9.16	114.10
1130.0	42.17	5.51	37.6	9.60	118.30
1200.0	43.55	5.92	44.3	9.89	121.10
1292.0	45.18	6.44	56.4	10.25	124.55
1400.0	46.73	6.99	78.9	10.60	127.93
1500.0	47.93	7.37	113.5	10.87	130.59



Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count bl/ft	Stroke ft	Energy kips-ft
700.0	29.87	0.00	14.1	7.61	106.97
800.0	30.61	0.41	17.8	7.86	107.73
900.0	31.20	0.85	23.3	8.07	108.22
1030.0	32.26	1.24	33.3	8.45	111.20
1130.0	32.91	1.42	46.2	8.72	113.64
1200.0	33.44	1.50	59.5	8.87	115.21
1300.0	33.90	1.62	94.3	8.95	115.36
1400.0	34.32	1.67	157.9	9.04	115.82
1500.0	34.73	1.61	261.8	9.09	115.79
1600.0	35.02	1.52	451.1	9.10	115.18

Flatiron, BR26P2, PP24x0.50, D100, 115ft, HI

Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count bl/ft	Stroke ft	Energy kips-ft
700.0	31.67	0.00	13.1	7.56	115.98
800.0	32.51	0.19	16.2	7.83	117.28
900.0	33.24	0.76	20.6	8.08	118.65
1030.0	34.39	1.13	28.3	8.48	122.36
1130.0	35.16	1.37	37.4	8.75	125.55
1200.0	35.62	1.46	46.2	8.92	127.42
1300.0	35.85	1.58	68.5	9.01	127.70
1400.0	36.26	1.66	104.8	9.13	128.87
1500.0	36.52	1.60	173.0	9.21	129.23
1600.0	36.85	1.53	271.0	9.24	128.98



Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count bl/ft	Stroke ft	Energy kips-ft
700.0	32.79	0.50	14.7	7.86	107.35
800.0	35.04	1.59	18.1	8.12	108.59
900.0	37.75	2.60	22.2	8.45	111.16
1030.0	40.67	3.37	29.4	8.85	114.60
1130.0	42.50	3.91	37.2	9.19	117.53
1200.0	43.56	4.21	44.6	9.40	119.48
1300.0	44.91	4.79	59.7	9.69	122.19
1400.0	46.26	5.23	84.7	9.96	124.71
1500.0	47.27	5.48	131.0	10.19	126.59
1600.0	47.87	5.69	237.9	10.25	126.95

Flatiron, BR26P2, PP24"x0.50", D100, 90ft, HI

Ultimate Capacity kips	Maximum Compression Stress ksi	Maximum Tension Stress ksi	Blow Count blows/ft	Stroke ft	Energy kips-ft
700.0	33.88	0.26	13.8	7.77	115.81
800.0	36.57	1.30	16.5	8.13	119.01
900.0	39.26	2.31	19.9	8.48	122.35
1030.0	42.62	3.25	25.6	8.90	126.50
1130.0	44.76	3.80	31.3	9.23	130.17
1200.0	45.94	4.15	36.8	9.43	132.05
1300.0	47.55	4.76	46.5	9.77	135.90
1400.0	48.82	5.27	61.2	10.05	139.00
1500.0	49.82	5.62	84.5	10.30	141.48
1600.0	50.67	5.88	124.7	10.51	143.83

Appendix A

INFORMATION ON USE OF GRLWEAP RESULTS AND GRLWEAP PROGRAM OUTPUT

The GRLWEAP wave equation program uses mathematical models that describe motions and forces within hammer, driving system, pile and soil under the hammer action. Under certain conditions, the models only crudely approximate complex, dynamic behavior. Input parameter values are partially or completely intended to model normal situations. In particular, the hammer data file supplied with the program assumes that the hammer is in good working order. Thus, in some cases the data supplied with the program and data selected by RMDT may reflect conditions that differ significantly from actual field conditions. The GRLWEAP program authors and RMDT recommend prudent and informed use of the GRLWEAP results. Generally, aspects of the soil response and hammer performance should be verified by dynamic measurements and CAPWAP analyses, static load testing, or other suitable methods of analysis and inspection.

Driving stresses computed by the GRLWEAP program do not include bending or other local non-axial stresses, prestresses or residual fabrication stresses. Thus, inspection based on GRLWEAP results must account for those and any other sources of additional stress.

All GRLWEAP results, including those from Bearing Graph or Inspector's Graph analyses should be used in conjunction with observed blow counts and observed strokes. However, time dependent soil strength changes, such as "setup" or "relaxation" may alter the soil resistance and produce long term ultimate bearing capacity values that differ substantially from those expected based on observed blow counts and wave equation analysis. Also, hammer strokes, transfer energy and soil resistance may vary over the interval that the blows are counted, especially for restrikes or piles driven to rock. Inspection procedures should account for these sources of variation or uncertainty.

The GRLWEAP soil resistance values are ultimate values for compressive (downward) pile loads. They MUST be reduced by an appropriate factor to yield a design or working load or factored resistance. If a factor is not specified in project documents selection or statement of an applicable factor of safety or a resistance factor should involve the foundation engineer or the engineer directing pile acceptance. RMDT recommends that the factor of safety or resistance factor reflect the quality of construction control, the variability of the site conditions, uncertainties in the loads, the nature of the structure, applicable codes, and other relevant factors.

Input File: G:\SHARED DRIVES\PJ\FLATIRON, 405 RENTON TO BELLEVUE DESIGN-BUILD
MULTIPLE BRIDGES\FLATIRON, BR 26E\FLATIRON, BR 26E PIER 2 ,PP24X0.50, D80, 90FT
HI.GWW

Hammer File: C:\ProgramData\PDI\GRLWEAP\2010\Resource\HAMMER2010.GW
Hammer File Version: 2003 (12/4/2018)

Input File Contents

Flatiron, BR26P2, PP24"x0.50", D80, 90ft, HI
OUT OSG HAM STR FUL PEL N SPL N-U P-D %SK ISM 0 PHI RSA ITR H-D MXT DEX
6 0 576 0 1 0 0 0 0 0 30 0 0 0 0 0 0 0 0 0 0 0 0 0 0.000
Pile g Hammer g Toe Area Pile Size Pile Type
32.170 32.170 36.910 24.000 Pipe
W Cp A Cp E Cp T Cp CoR ROut StCp
8.500 491.000 285.0 3.500 0.800 0.010 0.0
A Cu E Cu T Cu CoR ROut StCu
0.000 0.0 0.000 0.000 0.000 0.0
LPle APle EPle WPle Peri CI CoR ROut
90.000 36.91 30000.0 492.000 6.283 0 0.850 0.010
FFatigue F0 0-Bottom
0 0.000 0.000
Manufac Hmr Name HmrType No Seg-s
APE D 80-42 1 5
Ram Wt Ram L Ram Dia MaxStrk RtdStrk Efficcy
17.64 147.20 24.80 13.08 11.25 0.80
IB. Wt IB. L IB.Dia IB CoR IB RO
5.00 42.10 24.80 0.900 0.010
CompStrk A Chamber V Chamber C Delay C Duratn Exp Coeff VolCStart Vol CEnd
22.91 483.00 863.80 0.0010 0.0020 1.250 0.00 0.00
P atm P1 P2 P3 P4 P5
14.70 1410.00 1269.00 1142.00 1028.00 0.00
Stroke Effic. Pressure R-Weight T-Delay Exp-Coeff Eps-Str Total-AW
11.2000 0.8400 1480.0000 0.0000 0.0000 0.0100 0.0000
Qs Qt Js Jt Qx Jx Rati Dept
0.100 0.200 0.050 0.150 0.000 0.000 0.000 0.000
Research Soil Model: Atoe, Plug, Gap, Q-fac
0.000 0.000 0.000 0.000
Research Soil Model: RD-skn: m, d, toe: m, d
0.000 0.000 0.000 0.000
Research Toe Plug: Res-int, Q-int, D-int, Res-plug, Q-plug, D-plug
0.000 0.000 0.000 0.000 0.000
Research Toe Plug: RD plug toe: m, d
0.000 0.000
Research Toe Plug: New Toe Plug Model is NOT applied
Res. Distribution
Dpth Rskn Dpth Dpth
0.00 0.00 61.00 61.00 0.00 0.00 0.00 0.00 0.00 0.000
61.00 1.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.000
90.00 1.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.000
Rult
500.0 600.0 800.0 905.0 1030.0 1130.0 1200.0 1292.0 1400.0 1500.0

GRLWEAP: WAVE EQUATION ANALYSIS OF PILE FOUNDATIONS
 Version 2010
 English Units

Flatiron, BR26P2, PP24"x0.50", D80, 90ft, HI

Hammer Model:		D 80-42	Made by:	APE	
No.	Weight kips	Stiffn k/inch	CoR	C-Slk ft	Dampg k/ft/s
1	3.528				
2	3.528	475831.8	1.000	0.0000	
3	3.528	475831.8	1.000	0.0000	
4	3.528	475831.8	1.000	0.0000	
5	3.528	475831.8	1.000	0.0000	
Imp Block	5.000	195813.4	0.900	0.0100	
Helmet	8.500	39981.4	0.800	0.0100	20.3
Combined Pile Top		27682.5			

HAMMER OPTIONS:

Hammer File ID No.	576	Hammer Type	OE Diesel
Stroke Option	FxdP-VarS	Stroke Convergence Crit.	0.010
Fuel Pump Setting	Maximum		

HAMMER DATA:

Ram Weight	(kips)	17.64	Ram Length	(inch)	147.20
Maximum Stroke	(ft)	13.08			
Rated Stroke	(ft)	11.25	Efficiency		0.840
Maximum Pressure	(psi)	1410.00	Actual Pressure	(psi)	1480.00
Compression Exponent		1.350	Expansion Exponent		1.250
Ram Diameter	(inch)	24.80			
Combustion Delay	(s)	0.00100	Ignition Duration	(s)	0.00200

The Hammer Data Includes Estimated (NON-MEASURED) Quantities

HAMMER CUSHION			PILE CUSHION		
Cross Sect. Area	(in ²)	491.00	Cross Sect. Area	(in ²)	0.00
Elastic-Modulus	(ksi)	285.0	Elastic-Modulus	(ksi)	0.0
Thickness	(inch)	3.50	Thickness	(inch)	0.00
Coeff of Restitution		0.8	Coeff of Restitution		0.0
RoundOut	(ft)	0.0	RoundOut	(ft)	0.0
Stiffness	(kips/in)	39981.4	Stiffness	(kips/in)	0.0

PILE PROFILE:

Toe Area	(in2)	36.910	Pile Type	Pipe
Pile Size	(inch)	24.000		

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	36.91	30000.	492.0	6.3	0	16807.	65.9
90.0	36.91	30000.	492.0	6.3	0	16807.	65.9

Wave Travel Time 2L/c (ms) 10.710

No.	Weight	Pile and Soil Model				Soil-S	Soil-D	Capacity Quake	Rut LbTop	(kips) ft	500.0 ft	Area in2
		Stiffn	C-Slk	T-Slk	CoR							
1	0.420	27683	0.010	0.000	0.85	0.0	0.050	0.100	3.33	6.3	36.9	
2	0.420	27683	0.000	0.000	1.00	0.0	0.050	0.100	6.67	6.3	36.9	
9	0.420	27682	0.000	0.000	1.00	0.0	0.050	0.100	30.00	6.3	36.9	
10	0.420	27682	0.000	0.000	1.00	0.7	0.050	0.100	33.33	6.3	36.9	
11	0.420	27683	0.000	0.000	1.00	1.6	0.050	0.100	36.67	6.3	36.9	
12	0.420	27683	0.000	0.000	1.00	2.5	0.050	0.100	40.00	6.3	36.9	
13	0.420	27683	0.000	0.000	1.00	3.4	0.050	0.100	43.33	6.3	36.9	
14	0.420	27683	0.000	0.000	1.00	4.3	0.050	0.100	46.67	6.3	36.9	
15	0.420	27683	0.000	0.000	1.00	5.2	0.050	0.100	50.00	6.3	36.9	
16	0.420	27683	0.000	0.000	1.00	6.1	0.050	0.100	53.33	6.3	36.9	
17	0.420	27683	0.000	0.000	1.00	7.0	0.050	0.100	56.67	6.3	36.9	
18	0.420	27683	0.000	0.000	1.00	7.9	0.050	0.100	60.00	6.3	36.9	
19	0.420	27683	0.000	0.000	1.00	8.8	0.050	0.100	63.33	6.3	36.9	
20	0.420	27683	0.000	0.000	1.00	9.7	0.050	0.100	66.67	6.3	36.9	
21	0.420	27682	0.000	0.000	1.00	10.6	0.050	0.100	70.00	6.3	36.9	
22	0.420	27682	0.000	0.000	1.00	11.5	0.050	0.100	73.33	6.3	36.9	
23	0.420	27682	0.000	0.000	1.00	12.4	0.050	0.100	76.67	6.3	36.9	
24	0.420	27682	0.000	0.000	1.00	13.3	0.050	0.100	80.00	6.3	36.9	
25	0.420	27682	0.000	0.000	1.00	14.2	0.050	0.100	83.33	6.3	36.9	
26	0.420	27682	0.000	0.000	1.00	15.0	0.050	0.100	86.67	6.3	36.9	
27	0.420	27683	0.000	0.000	1.00	15.9	0.050	0.100	90.00	6.3	36.9	
Toe			350.0			0.150	0.200					

11.350 kips total unreduced pile weight (g= 32.17 ft/s²)

11.350 kips total reduced pile weight (g= 32.17 ft/s²)

PILE, SOIL, ANALYSIS OPTIONS:

Uniform pile		Pile Segments: Automatic	
No. of Slacks/Splices	0	Pile Damping (%)	1
Pile Penetration (ft)	61.00	Pile Damping Fact.(k/ft/s)	1.318
% Shaft Resistance	30		
Soil Damping Option	Smith		
Max No Analysis Iterations	0	Time Increment/Critical	160
Output Time Interval	1	Analysis Time-Input (ms)	0
Output Level: Variable vs Time			
Gravity Mass, Pile, Hammer:	32.170	32.170	32.170
Output Segment Generation:	Automatic		

No	Rut= 500.0, Rtoe = 350.0	kips, Time Inc. =0.087 ms	max Et				
	mxTForce kips	mxCForce kips	mxTStrss ksi	mxCStrss ksi	max V ft/s	max D inch	
1	0.0	1034.0	0.00	28.02	14.06	1.741	101.19
2	-4.3	1036.4	-0.12	28.08	14.03	1.725	100.98
3	-8.5	1039.8	-0.23	28.17	14.03	1.708	100.77
4	-12.7	1043.2	-0.34	28.26	14.02	1.692	100.54
5	-16.9	1045.6	-0.46	28.33	13.99	1.675	100.30
6	-21.0	1049.1	-0.57	28.42	13.99	1.658	100.05
7	-25.1	1052.4	-0.68	28.51	13.97	1.641	99.80
8	-29.0	1054.5	-0.79	28.57	13.93	1.624	99.56
9	-32.9	1058.7	-0.89	28.68	13.92	1.608	99.33
10	-36.7	1062.1	-0.99	28.78	13.88	1.592	99.05
11	-39.7	1063.9	-1.08	28.82	13.83	1.576	98.62
12	-41.7	1066.2	-1.13	28.89	13.80	1.559	98.03
13	-42.8	1066.0	-1.16	28.88	13.74	1.543	97.29
14	-43.3	1064.8	-1.17	28.85	13.67	1.527	96.41
15	-42.8	1063.1	-1.16	28.80	13.61	1.510	95.38
16	-41.3	1059.0	-1.12	28.69	13.53	1.494	94.21
17	-38.7	1054.9	-1.05	28.58	13.45	1.478	92.91
18	-35.2	1049.5	-0.95	28.43	13.37	1.462	91.48
19	-30.7	1041.7	-0.83	28.22	13.27	1.446	89.94
20	-25.0	1034.8	-0.68	28.04	13.17	1.430	88.27
21	-18.3	1025.8	-0.50	27.79	13.08	1.415	86.50
22	-10.4	1013.7	-0.28	27.46	12.99	1.400	84.61
23	-1.5	997.2	-0.04	27.02	13.08	1.386	82.62
24	0.0	964.7	0.00	26.14	13.50	1.371	80.52
25	0.0	934.7	0.00	25.32	13.98	1.357	78.31
26	0.0	909.0	0.00	24.63	13.70	1.344	76.01
27	0.0	972.1	0.00	26.34	12.24	1.331	74.75

(Eq) Strokes Analyzed and Last Return (ft):
 11.20 6.84 7.31 7.24

Max. Combustion Pressure 1480.0 psi

No	Rut= 600.0, Rtoe = 420.0	kips, Time Inc. =0.087 ms	max Et				
	mxTForce kips	mxCForce kips	mxTStrss ksi	mxCStrss ksi	max V ft/s	max D inch	
1	0.0	1069.3	0.00	28.97	14.57	1.644	102.08
2	-6.5	1072.7	-0.18	29.06	14.56	1.622	101.59
3	-12.5	1075.4	-0.34	29.14	14.54	1.599	101.10
4	-18.0	1079.0	-0.49	29.23	14.54	1.577	100.60
5	-23.3	1082.8	-0.63	29.34	14.52	1.555	100.11
6	-28.6	1085.2	-0.77	29.40	14.49	1.533	99.62
7	-33.7	1089.2	-0.91	29.51	14.48	1.511	99.13
8	-38.6	1092.8	-1.05	29.61	14.45	1.489	98.64
9	-43.7	1095.3	-1.18	29.67	14.41	1.467	98.15
10	-48.6	1100.3	-1.32	29.81	14.38	1.445	97.59
11	-52.4	1102.9	-1.42	29.88	14.33	1.423	96.88
12	-54.7	1103.8	-1.48	29.91	14.26	1.400	96.00
13	-56.0	1104.6	-1.52	29.93	14.21	1.379	94.97
14	-56.0	1102.4	-1.52	29.87	14.13	1.357	93.79
15	-54.9	1099.8	-1.49	29.80	14.04	1.335	92.48
16	-52.9	1096.1	-1.43	29.70	13.96	1.314	91.05
17	-50.0	1089.5	-1.35	29.52	13.86	1.294	89.49
18	-46.0	1103.9	-1.25	29.91	13.75	1.274	87.83
19	-40.9	1133.9	-1.11	30.72	13.64	1.254	86.05
20	-35.0	1122.0	-0.95	30.40	13.50	1.234	84.18
21	-28.1	1095.7	-0.76	29.69	13.37	1.215	82.21
22	-20.0	1080.3	-0.54	29.27	13.27	1.196	80.15
23	-10.7	1063.5	-0.29	28.81	13.29	1.178	78.00
24	-0.4	1043.2	-0.01	28.26	13.63	1.161	75.76
25	0.0	1022.2	0.00	27.69	13.96	1.144	73.46
26	0.0	998.7	0.00	27.06	13.46	1.127	71.08
27	0.0	1059.3	0.00	28.70	11.71	1.111	69.75

(Eq) Strokes Analyzed and Last Return (ft):
 11.20 7.29 7.65 7.60

Max. Combustion Pressure 1480.0 psi

No	Rut= 800.0, Rtoe = 560.0	kips, Time Inc. =0.074 ms	max Et				
	mxTForce kips	mxCForce kips	mxTStrss ksi	mxCStrss ksi	max V ft/s	max D inch	
1	0.0	1269.0	0.00	34.38	15.60	1.583	106.70
2	-13.2	1239.2	-0.36	33.57	15.60	1.549	105.42
3	-25.6	1229.1	-0.69	33.30	15.58	1.515	104.15
4	-37.3	1230.4	-1.01	33.34	15.57	1.481	102.93
5	-48.7	1227.5	-1.32	33.26	15.56	1.448	101.77
6	-59.3	1236.4	-1.61	33.50	15.54	1.416	100.64
7	-69.5	1242.2	-1.88	33.65	15.51	1.384	99.52
8	-79.8	1245.6	-2.16	33.75	15.48	1.352	98.40
9	-89.4	1242.0	-2.42	33.65	15.45	1.320	97.26
10	-98.0	1232.8	-2.66	33.40	15.40	1.287	96.02
11	-104.6	1228.2	-2.83	33.27	15.33	1.255	94.59
12	-108.9	1213.1	-2.95	32.87	15.26	1.222	92.98
13	-111.9	1204.4	-3.03	32.63	15.19	1.191	91.24
14	-115.7	1196.7	-3.14	32.42	15.09	1.160	89.36
15	-117.8	1189.9	-3.19	32.24	14.96	1.129	87.37
16	-117.2	1182.7	-3.18	32.04	14.85	1.099	85.27
17	-115.0	1226.3	-3.12	33.22	14.72	1.070	83.06
18	-111.4	1282.1	-3.02	34.74	14.56	1.041	80.75
19	-105.6	1319.4	-2.86	35.75	14.39	1.011	78.32
20	-97.7	1316.5	-2.65	35.67	14.22	0.982	75.79
21	-89.2	1270.8	-2.42	34.43	14.03	0.953	73.18
22	-79.3	1246.1	-2.15	33.76	13.84	0.925	70.58
23	-68.7	1213.5	-1.86	32.88	13.77	0.899	68.01
24	-57.5	1189.2	-1.56	32.22	13.95	0.874	65.43
25	-45.7	1168.9	-1.24	31.67	14.02	0.851	62.87
26	-32.9	1149.2	-0.89	31.14	13.08	0.828	60.33
27	-18.2	1178.3	-0.49	31.92	10.78	0.807	58.82

(Eq) Strokes Analyzed and Last Return (ft):
 11.20 8.18 8.32 8.31

Max. Combustion Pressure 1480.0 psi

No	Rut= 905.0, Rtoe = 633.5	kips, Time Inc. =0.069 ms	max Et				
	mxTForce kips	mxCForce kips	mxTStrss ksi	mxCStrss ksi	max V ft/s	max D inch	
1	0.0	1380.6	0.00	37.40	16.19	1.581	110.40
2	-16.0	1355.7	-0.43	36.73	16.19	1.542	108.76
3	-31.1	1335.5	-0.84	36.18	16.18	1.503	107.06
4	-45.4	1335.8	-1.23	36.19	16.17	1.463	105.32
5	-59.4	1332.9	-1.61	36.11	16.16	1.424	103.62
6	-72.5	1344.0	-1.96	36.41	16.14	1.386	102.04
7	-85.4	1353.6	-2.32	36.67	16.12	1.349	100.53
8	-98.1	1361.1	-2.66	36.88	16.09	1.313	99.07
9	-110.2	1356.7	-2.98	36.76	16.05	1.277	97.60
10	-121.8	1345.0	-3.30	36.44	15.99	1.240	96.03
11	-132.2	1330.5	-3.58	36.05	15.92	1.203	94.24
12	-140.3	1317.2	-3.80	35.69	15.84	1.167	92.22
13	-145.7	1305.6	-3.95	35.37	15.74	1.130	90.01
14	-148.3	1296.0	-4.02	35.11	15.63	1.094	87.66
15	-147.9	1288.8	-4.01	34.92	15.50	1.058	85.22
16	-144.2	1282.7	-3.91	34.75	15.36	1.024	82.71
17	-140.3	1303.0	-3.80	35.30	15.20	0.991	80.13
18	-138.5	1358.9	-3.75	36.82	15.02	0.958	77.49
19	-134.1	1398.4	-3.63	37.89	14.83	0.925	74.77
20	-127.1	1398.7	-3.44	37.89	14.63	0.893	71.96
21	-118.7	1356.3	-3.22	36.75	14.41	0.861	69.05
22	-108.1	1319.3	-2.93	35.74	14.21	0.828	66.06
23	-95.0	1282.5	-2.57	34.75	14.08	0.796	63.06
24	-80.5	1256.0	-2.18	34.03	14.18	0.766	60.20
25	-66.6	1235.3	-1.80	33.47	14.14	0.739	57.45
26	-50.2	1217.4	-1.36	32.98	12.96	0.713	54.80
27	-28.3	1231.8	-0.77	33.37	10.36	0.689	53.18

(Eq) Strokes Analyzed and Last Return (ft):
 11.20 8.62 8.73 8.72
 Max. Combustion Pressure 1480.0 psi

No	Rut= 1030.0, Rtoe = 721.0	kips, Time Inc. =0.063 ms	max Et				
	mxTForce kips	mxCForce kips	mxTStrss ksi	mxCStrss ksi	max V ft/s	max D inch	
1	0.0	1482.7	0.00	40.17	16.77	1.580	114.10
2	-19.7	1466.5	-0.53	39.73	16.76	1.537	112.07
3	-37.5	1444.5	-1.02	39.14	16.75	1.493	109.94
4	-53.9	1437.2	-1.46	38.94	16.75	1.449	107.72
5	-69.9	1437.0	-1.89	38.93	16.74	1.404	105.45
6	-84.9	1448.2	-2.30	39.24	16.72	1.359	103.22
7	-100.4	1463.6	-2.72	39.65	16.69	1.316	101.16
8	-115.1	1473.4	-3.12	39.92	16.66	1.275	99.22
9	-129.6	1470.1	-3.51	39.83	16.62	1.234	97.35
10	-144.4	1455.3	-3.91	39.43	16.56	1.193	95.38
11	-156.7	1436.2	-4.24	38.91	16.48	1.152	93.18
12	-166.4	1419.4	-4.51	38.46	16.39	1.111	90.72
13	-174.0	1404.8	-4.71	38.06	16.29	1.070	88.02
14	-179.2	1393.0	-4.86	37.74	16.17	1.028	85.13
15	-181.9	1385.5	-4.93	37.54	16.01	0.988	82.12
16	-181.1	1379.6	-4.91	37.38	15.85	0.948	79.08
17	-177.0	1375.8	-4.79	37.27	15.67	0.910	76.02
18	-168.8	1431.9	-4.57	38.79	15.46	0.873	72.95
19	-157.5	1470.8	-4.27	39.85	15.24	0.837	69.87
20	-148.6	1473.2	-4.03	39.91	15.00	0.801	66.74
21	-141.4	1439.6	-3.83	39.00	14.75	0.766	63.54
22	-131.1	1392.0	-3.55	37.71	14.51	0.730	60.26
23	-118.5	1353.7	-3.21	36.67	14.33	0.693	56.92
24	-104.3	1322.1	-2.83	35.82	14.35	0.657	53.60
25	-88.5	1300.9	-2.40	35.25	14.13	0.624	50.51
26	-66.7	1285.0	-1.81	34.82	12.67	0.594	47.69
27	-37.3	1281.0	-1.01	34.71	9.85	0.566	45.93

(Eq) Strokes Analyzed and Last Return (ft):
 11.20 9.16 9.24

Max. Combustion Pressure 1480.0 psi

No	Rut= 1130.0, Rtoe = 791.0	kips, Time Inc. =0.058 ms	max Et				
	mxTForce kips	mxCForce kips	mxTStrss ksi	mxCStrss ksi	max V ft/s	max D inch	
1	0.0	1556.5	0.00	42.17	17.34	1.590	118.30
2	-22.9	1545.4	-0.62	41.87	17.34	1.544	115.93
3	-42.9	1527.9	-1.16	41.39	17.33	1.497	113.47
4	-61.1	1513.6	-1.65	41.01	17.32	1.450	110.90
5	-78.3	1513.7	-2.12	41.01	17.31	1.401	108.22
6	-94.7	1525.1	-2.56	41.32	17.29	1.352	105.52
7	-111.4	1543.5	-3.02	41.82	17.28	1.304	102.97
8	-127.5	1555.5	-3.45	42.14	17.23	1.259	100.62
9	-144.0	1553.4	-3.90	42.09	17.20	1.214	98.38
10	-160.2	1536.1	-4.34	41.62	17.13	1.170	96.09
11	-173.7	1514.0	-4.70	41.02	17.06	1.126	93.56
12	-185.2	1493.7	-5.02	40.47	16.95	1.082	90.75
13	-194.0	1476.8	-5.26	40.01	16.84	1.038	87.67
14	-199.6	1464.1	-5.41	39.67	16.69	0.993	84.37
15	-202.4	1455.9	-5.48	39.44	16.53	0.949	80.92
16	-203.2	1450.1	-5.51	39.29	16.34	0.906	77.42
17	-201.2	1442.8	-5.45	39.09	16.14	0.864	73.93
18	-195.3	1490.7	-5.29	40.39	15.91	0.824	70.48
19	-184.1	1527.5	-4.99	41.38	15.66	0.784	67.06
20	-168.7	1528.5	-4.57	41.41	15.41	0.746	63.64
21	-153.6	1500.4	-4.16	40.65	15.12	0.708	60.18
22	-142.7	1453.4	-3.87	39.38	14.85	0.670	56.66
23	-130.7	1408.4	-3.54	38.16	14.62	0.631	53.08
24	-116.5	1373.1	-3.16	37.20	14.57	0.592	49.49
25	-99.8	1352.1	-2.70	36.63	14.23	0.554	46.04
26	-75.4	1337.6	-2.04	36.24	12.57	0.520	43.00
27	-41.8	1327.1	-1.13	35.95	9.54	0.489	41.08

(Eq) Strokes Analyzed and Last Return (ft):
 11.20 9.60 9.64

Max. Combustion Pressure 1480.0 psi

No	Rut= 1200.0, Rtoe = 840.0	kips, Time Inc. =0.056 ms	max Et				
	mxTForce kips	mxCForce kips	mxTStrss ksi	mxCStrss ksi	max V ft/s	max D inch	
1	0.0	1600.9	0.00	43.37	17.72	1.598	121.10
2	-26.0	1592.6	-0.71	43.15	17.71	1.550	118.50
3	-47.8	1579.9	-1.29	42.80	17.71	1.501	115.81
4	-67.2	1563.8	-1.82	42.37	17.71	1.451	112.99
5	-85.1	1560.9	-2.31	42.29	17.69	1.400	110.05
6	-102.8	1574.1	-2.78	42.65	17.68	1.348	107.05
7	-120.2	1593.3	-3.26	43.17	17.66	1.298	104.17
8	-137.3	1607.2	-3.72	43.54	17.61	1.249	101.53
9	-154.9	1604.9	-4.20	43.48	17.58	1.203	99.05
10	-172.0	1586.7	-4.66	42.99	17.51	1.157	96.52
11	-186.6	1562.8	-5.05	42.34	17.42	1.111	93.76
12	-199.0	1540.6	-5.39	41.74	17.32	1.065	90.71
13	-208.3	1522.0	-5.64	41.23	17.19	1.018	87.37
14	-214.3	1508.2	-5.81	40.86	17.04	0.971	83.80
15	-217.5	1499.7	-5.89	40.63	16.87	0.925	80.05
16	-218.4	1494.4	-5.92	40.49	16.66	0.879	76.25
17	-216.7	1487.0	-5.87	40.29	16.44	0.835	72.48
18	-211.2	1527.2	-5.72	41.38	16.20	0.793	68.77
19	-201.3	1562.7	-5.45	42.34	15.94	0.752	65.11
20	-186.7	1561.0	-5.06	42.29	15.66	0.712	61.47
21	-167.9	1535.9	-4.55	41.61	15.35	0.672	57.81
22	-150.7	1493.2	-4.08	40.46	15.05	0.632	54.12
23	-137.9	1441.9	-3.74	39.06	14.81	0.591	50.38
24	-123.4	1404.9	-3.34	38.06	14.70	0.551	46.63
25	-105.9	1383.9	-2.87	37.49	14.25	0.510	42.99
26	-79.6	1369.8	-2.16	37.11	12.47	0.473	39.76
27	-43.8	1355.8	-1.19	36.73	9.33	0.441	37.73

(Eq) Strokes Analyzed and Last Return (ft):
 11.20 9.89 9.90

Max. Combustion Pressure 1480.0 psi

No	Rut= 1292.0, Rtoe = 904.4	kips, Time Inc. =0.053 ms	max Et				
	mxTForce kips	mxCForce kips	mxTStrss ksi	mxCStrss ksi	max V ft/s	max D inch	
1	0.0	1652.0	0.00	44.76	18.17	1.607	124.55
2	-30.2	1645.0	-0.82	44.57	18.18	1.556	121.64
3	-55.2	1638.1	-1.50	44.38	18.17	1.505	118.65
4	-75.9	1625.6	-2.06	44.04	18.16	1.452	115.53
5	-94.6	1616.7	-2.56	43.80	18.15	1.399	112.28
6	-113.9	1632.5	-3.09	44.23	18.13	1.344	108.92
7	-132.4	1651.4	-3.59	44.74	18.11	1.291	105.63
8	-151.0	1667.5	-4.09	45.18	18.08	1.239	102.62
9	-169.5	1664.5	-4.59	45.10	18.04	1.189	99.81
10	-187.5	1644.8	-5.08	44.56	17.97	1.141	96.99
11	-203.5	1618.2	-5.51	43.84	17.87	1.092	93.94
12	-217.0	1595.3	-5.88	43.22	17.75	1.044	90.58
13	-226.7	1576.3	-6.14	42.71	17.62	0.995	86.92
14	-232.9	1561.3	-6.31	42.30	17.45	0.946	82.99
15	-237.0	1553.0	-6.42	42.07	17.26	0.897	78.88
16	-237.8	1548.0	-6.44	41.94	17.05	0.848	74.70
17	-235.5	1540.3	-6.38	41.73	16.80	0.802	70.57
18	-229.5	1571.0	-6.22	42.56	16.54	0.757	66.53
19	-220.7	1604.5	-5.98	43.47	16.26	0.713	62.56
20	-207.1	1599.2	-5.61	43.33	15.96	0.671	58.64
21	-188.4	1574.1	-5.11	42.65	15.63	0.629	54.73
22	-165.9	1538.4	-4.50	41.68	15.29	0.587	50.81
23	-146.4	1482.3	-3.97	40.16	15.00	0.544	46.86
24	-131.5	1444.0	-3.56	39.12	14.84	0.501	42.92
25	-113.1	1422.3	-3.06	38.53	14.28	0.459	39.08
26	-85.7	1408.4	-2.32	38.16	12.32	0.418	35.60
27	-48.4	1388.7	-1.31	37.63	9.06	0.383	33.41

(Eq) Strokes Analyzed and Last Return (ft):
 11.20 10.25 10.23

Max. Combustion Pressure 1480.0 psi

No	Rut= 1400.0, Rtoe = 980.0	kips, Time Inc. =0.049 ms	max Et				
	mxTForce kips	mxCForce kips	mxTStrss ksi	mxCStrss ksi	max V ft/s	max D inch	
1	0.0	1701.2	0.00	46.09	18.62	1.615	127.93
2	-33.5	1693.0	-0.91	45.87	18.62	1.561	124.63
3	-62.4	1688.3	-1.69	45.74	18.61	1.507	121.34
4	-85.8	1683.9	-2.33	45.62	18.61	1.452	117.92
5	-105.1	1674.8	-2.85	45.38	18.59	1.400	114.35
6	-125.3	1687.5	-3.39	45.72	18.58	1.350	111.36
7	-145.1	1708.9	-3.93	46.30	18.56	1.297	108.20
8	-165.8	1725.0	-4.49	46.73	18.53	1.242	104.78
9	-185.5	1722.7	-5.02	46.67	18.48	1.186	101.27
10	-204.0	1700.8	-5.53	46.08	18.40	1.131	97.68
11	-221.5	1670.7	-6.00	45.26	18.30	1.077	93.85
12	-235.8	1645.1	-6.39	44.57	18.18	1.023	90.13
13	-246.0	1626.9	-6.66	44.08	18.02	0.970	86.11
14	-252.9	1615.0	-6.85	43.76	17.84	0.918	81.81
15	-257.3	1606.9	-6.97	43.54	17.63	0.866	77.29
16	-258.1	1602.5	-6.99	43.42	17.39	0.815	72.69
17	-255.0	1595.7	-6.91	43.23	17.13	0.766	68.15
18	-248.6	1614.4	-6.74	43.74	16.85	0.718	63.74
19	-239.7	1645.2	-6.49	44.57	16.54	0.672	59.43
20	-226.7	1635.2	-6.14	44.30	16.21	0.628	55.22
21	-208.5	1605.9	-5.65	43.51	15.85	0.584	51.05
22	-184.6	1572.6	-5.00	42.61	15.47	0.540	46.91
23	-156.8	1524.1	-4.25	41.29	15.12	0.495	42.77
24	-138.0	1481.0	-3.74	40.12	14.90	0.450	38.64
25	-120.3	1459.0	-3.26	39.53	14.21	0.405	34.60
26	-93.2	1445.4	-2.53	39.16	12.07	0.361	30.86
27	-53.3	1417.6	-1.44	38.41	8.72	0.322	28.43

(Eq) Strokes Analyzed and Last Return (ft):
 11.20 10.60 10.58

Max. Combustion Pressure 1480.0 psi

No	Rut= 1500.0, Rtoe = 1050.0	kips, Time Inc. =0.047 ms	max Et				
	mxTForce kips	mxCForce kips	mxTStrss ksi	mxCStrss ksi	max V ft/s	max D inch	
1	0.0	1738.8	0.00	47.11	18.96	1.621	130.59
2	-34.8	1729.3	-0.94	46.85	18.96	1.565	127.05
3	-65.9	1722.2	-1.79	46.66	18.96	1.509	123.53
4	-91.6	1718.8	-2.48	46.57	18.95	1.454	119.88
5	-112.7	1712.6	-3.05	46.40	18.94	1.405	116.89
6	-134.4	1729.5	-3.64	46.86	18.93	1.354	113.90
7	-155.6	1752.0	-4.22	47.47	18.90	1.300	110.59
8	-177.8	1769.0	-4.82	47.93	18.88	1.244	106.99
9	-198.0	1765.2	-5.36	47.82	18.82	1.186	103.24
10	-217.6	1741.9	-5.89	47.19	18.73	1.130	99.42
11	-235.8	1707.4	-6.39	46.26	18.64	1.073	95.33
12	-250.2	1678.3	-6.78	45.47	18.50	1.018	91.02
13	-260.4	1658.2	-7.05	44.93	18.33	0.962	86.38
14	-267.7	1647.0	-7.25	44.62	18.14	0.908	81.66
15	-271.6	1643.9	-7.36	44.54	17.91	0.854	76.75
16	-271.9	1642.9	-7.37	44.51	17.65	0.798	71.54
17	-267.4	1637.4	-7.24	44.36	17.38	0.744	66.46
18	-260.4	1648.4	-7.05	44.66	17.07	0.691	61.71
19	-250.1	1676.5	-6.78	45.42	16.74	0.643	57.10
20	-236.5	1662.4	-6.41	45.04	16.38	0.596	52.60
21	-217.9	1628.5	-5.90	44.12	15.99	0.550	48.19
22	-193.1	1592.0	-5.23	43.13	15.57	0.504	43.84
23	-162.5	1542.3	-4.40	41.78	15.20	0.459	39.52
24	-138.9	1504.5	-3.76	40.76	14.89	0.412	35.24
25	-121.7	1487.1	-3.30	40.29	14.09	0.365	31.03
26	-95.3	1472.7	-2.58	39.90	11.81	0.318	27.07
27	-55.0	1443.8	-1.49	39.12	8.41	0.276	24.36

(Eq) Strokes Analyzed and Last Return (ft):
 11.20 10.87 10.83

Max. Combustion Pressure 1480.0 psi

Rut kips	B1 b/ft	Ct	Stroke down	(ft) up	Ten ksi	Str ksi	i	t	Comp ksi	Str ksi	i	t	ENTHRU kip-ft	B1 b/min	Rt
500.0	10.3	7.31	7.24	-1.17	14	47	28.89	12	5	101.2	43.4				
600.0	12.7	7.65	7.60	-1.52	14	40	30.72	19	10	102.1	42.4				
800.0	18.8	8.32	8.31	-3.19	15	35	35.75	19	10	106.7	40.7				
905.0	23.1	8.73	8.72	-4.02	14	33	37.89	20	10	110.4	39.7				
1030.0	30.3	9.16	9.24	-4.93	15	32	40.17	1	14	114.1	38.7				
1130.0	37.6	9.60	9.64	-5.51	16	32	42.17	1	14	118.3	37.8				
1200.0	44.3	9.89	9.90	-5.92	16	31	43.54	8	15	121.1	37.3				
1292.0	56.4	10.25	10.23	-6.44	16	31	45.18	8	15	124.6	36.7				
1400.0	78.9	10.60	10.58	-6.99	16	30	46.73	8	15	127.9	36.1				
1500.0	113.5	10.87	10.83	-7.37	16	30	47.93	8	15	130.6	35.7				

Input File: G:\SHARED DRIVES\PJ\FLATIRON, 405 RENTON TO BELLEVUE DESIGN-BUILD
 MULTIPLE BRIDGES\FLATIRON, BR 26E\FLATIRON, BR 26E PIER 2 ,PP24X0.50, D100, 90FT
 HI.GWW

Hammer File: C:\ProgramData\PDI\GRLWEAP\2010\Resource\HAMMER2010.GW
 Hammer File Version: 2003 (12/4/2018)

Input File Contents

Flatiron, BR26P2, PP24"x0.50", D100, 90ft, HI

OUT	OSG	HAM	STR	FUL	PEL	N	SPL	N-U	P-D	%SK	ISM	O	PHI	RSA	ITR	H-D	MXT	DEX
6	0	577	0	1	0	0	0	0	0	30	0	0	0	0	0	0	0	0.000
Pile g Hammer g Toe Area Pile Size										Pile Type								
32.170		32.170		36.910		24.000												Pipe
W Cp		A Cp		E Cp		T Cp		CoR		ROut		StCp						
8.500		491.000		285.0		3.500		0.800		0.010		0.0						
A Cu		E Cu		T Cu		CoR		ROut		StCu								
0.000		0.0		0.000		0.000		0.000		0.0								
LPle		APle		EPle		WPle		Peri		CI		CoR						
90.000		36.91		30000.0		492.000		6.283		0		0.850					ROut	
FFatigue		F0		0-Bottom													0.010	
0		0.000		0.000														
Manufac	Hmr	Name	HmrType	No	Seg-s													
APE	D	100-42		1		7												
Ram Wt		Ram L		Ram Dia		MaxStrk		RtdStrk		Efficcy								
22.05		187.80		24.80		13.08		11.25		0.80								
IB. Wt		IB. L		IB.Dia		IB CoR		IB RO										
5.00		42.10		24.80		0.900		0.010										
CompStrk	A	Chamber	V	Chamber	C	Delay	C	Duratn	Exp	Coeff	VolCStart	Vol	CEnd					
28.35		483.00		1080.00		0.0010		0.0020		1.250		0.00		0.00				
P atm		P1		P2		P3		P4		P5								
14.70		1425.00		1282.00		1154.00		1039.00		0.00								
Stroke	Effic.	Pressure	R-Weight		T-Delay		Exp-Coeff		Eps-Str		Total-AW							
11.2000		0.8400	1425.0000		0.0000		0.0000		0.0100		0.0000							
Qs	Qt	Js	Jt		Qx		Jx		Rati		Dept							
0.100	0.200	0.050	0.150		0.000		0.000		0.000		0.000							
Research	Soil Model:	Atoe, Plug, Gap, Q-fac																
0.000	0.000	0.000	0.000															
Research	Soil Model:	RD-skn: m, d, toe: m, d																
0.000	0.000	0.000	0.000															
Research	Toe Plug:	Res-int, Q-int, D-int, Res-plug, Q-plug, D-plug																
0.000	0.000	0.000	0.000		0.000		0.000		0.000									
Research	Toe Plug:	RD plug toe: m, d																
0.000	0.000																	
Research	Toe Plug:	New Toe Plug Model is NOT applied																
Res. Distribution																		
Dpth	Rskn	Dpth	Dpth															
0.00	0.00	61.00	61.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
61.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
90.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
Rult																		
700.0	800.0	900.0	1030.0	1130.0	1200.0	1300.0	1400.0	1500.0	1600.0									

GRLWEAP: WAVE EQUATION ANALYSIS OF PILE FOUNDATIONS
 Version 2010
 English Units

Flatiron, BR26P2, PP24"x0.50", D100, 90ft, HI

Hammer Model:		D 100-42	Made by:	APE	
No.	Weight kips	Stiffn k/inch	CoR	C-Slk ft	Dampg k/ft/s
1	3.150				
2	3.150	522148.1	1.000	0.0000	
3	3.150	522148.1	1.000	0.0000	
4	3.150	522148.1	1.000	0.0000	
5	3.150	522148.1	1.000	0.0000	
6	3.150	522148.1	1.000	0.0000	
7	3.150	522148.1	1.000	0.0000	
Imp Block	5.000	203231.9	0.900	0.0100	
Helmet	8.500	39981.4	0.800	0.0100	19.5
Combined Pile Top		27682.5			

HAMMER OPTIONS:

Hammer File ID No.	577	Hammer Type	OE Diesel
Stroke Option	FxdP-VarS	Stroke Convergence Crit.	0.010
Fuel Pump Setting	Maximum		

HAMMER DATA:

Ram Weight	(kips)	22.05	Ram Length	(inch)	187.80
Maximum Stroke	(ft)	13.08			
Rated Stroke	(ft)	11.25	Efficiency		0.840
Maximum Pressure	(psi)	1425.00	Actual Pressure	(psi)	1425.00
Compression Exponent		1.350	Expansion Exponent		1.250
Ram Diameter	(inch)	24.80			
Combustion Delay	(s)	0.00100	Ignition Duration	(s)	0.00200

The Hammer Data Includes Estimated (NON-MEASURED) Quantities

HAMMER CUSHION

Cross Sect. Area	(in ²)	491.00	PILE CUSHION	
Elastic-Modulus	(ksi)	285.0	Cross Sect. Area	(in ²)
Thickness	(inch)	3.50	Elastic-Modulus	(ksi)
Coeff of Restitution		0.8	Thickness	(inch)
RoundOut	(ft)	0.0	Coeff of Restitution	0.0
Stiffness	(kips/in)	39981.4	RoundOut	(ft)
			Stiffness	(kips/in)

PILE PROFILE:

Toe Area	(in2)	36.910	Pile Type	Pipe
Pile Size	(inch)	24.000		

L b Top	Area	E-Mod	Spec Wt	Perim	C Index	Wave Sp	EA/c
ft	in2	ksi	lb/ft3	ft		ft/s	k/ft/s
0.0	36.91	30000.	492.0	6.3	0	16807.	65.9
90.0	36.91	30000.	492.0	6.3	0	16807.	65.9

Wave Travel Time 2L/c (ms) 10.710

No.	Weight	Pile and Soil Model				Soil-S	Soil-D	Capacity Quake	Rut LbTop	(kips) ft	700.0 ft	Area in2
		Stiffn kips	C-Slk ft/in	T-Slk ft	CoR							
1	0.420	27683	0.010	0.000	0.85	0.0	0.050	0.100	3.33	6.3	36.9	
2	0.420	27683	0.000	0.000	1.00	0.0	0.050	0.100	6.67	6.3	36.9	
9	0.420	27682	0.000	0.000	1.00	0.1	0.050	0.100	30.00	6.3	36.9	
10	0.420	27682	0.000	0.000	1.00	1.0	0.050	0.100	33.33	6.3	36.9	
11	0.420	27683	0.000	0.000	1.00	2.3	0.050	0.100	36.67	6.3	36.9	
12	0.420	27683	0.000	0.000	1.00	3.5	0.050	0.100	40.00	6.3	36.9	
13	0.420	27683	0.000	0.000	1.00	4.8	0.050	0.100	43.33	6.3	36.9	
14	0.420	27683	0.000	0.000	1.00	6.0	0.050	0.100	46.67	6.3	36.9	
15	0.420	27683	0.000	0.000	1.00	7.3	0.050	0.100	50.00	6.3	36.9	
16	0.420	27683	0.000	0.000	1.00	8.5	0.050	0.100	53.33	6.3	36.9	
17	0.420	27683	0.000	0.000	1.00	9.8	0.050	0.100	56.67	6.3	36.9	
18	0.420	27683	0.000	0.000	1.00	11.0	0.050	0.100	60.00	6.3	36.9	
19	0.420	27683	0.000	0.000	1.00	12.3	0.050	0.100	63.33	6.3	36.9	
20	0.420	27683	0.000	0.000	1.00	13.5	0.050	0.100	66.67	6.3	36.9	
21	0.420	27682	0.000	0.000	1.00	14.8	0.050	0.100	70.00	6.3	36.9	
22	0.420	27682	0.000	0.000	1.00	16.1	0.050	0.100	73.33	6.3	36.9	
23	0.420	27682	0.000	0.000	1.00	17.3	0.050	0.100	76.67	6.3	36.9	
24	0.420	27682	0.000	0.000	1.00	18.6	0.050	0.100	80.00	6.3	36.9	
25	0.420	27682	0.000	0.000	1.00	19.8	0.050	0.100	83.33	6.3	36.9	
26	0.420	27682	0.000	0.000	1.00	21.1	0.050	0.100	86.67	6.3	36.9	
27	0.420	27683	0.000	0.000	1.00	22.3	0.050	0.100	90.00	6.3	36.9	
Toe						490.0	0.150	0.200				

11.350 kips total unreduced pile weight (g= 32.17 ft/s²)

11.350 kips total reduced pile weight (g= 32.17 ft/s²)

PILE, SOIL, ANALYSIS OPTIONS:

Uniform pile		Pile Segments: Automatic	
No. of Slacks/Splices	0	Pile Damping (%)	1
Pile Penetration (ft)	61.00	Pile Damping Fact.(k/ft/s)	1.318
% Shaft Resistance	30		
Soil Damping Option	Smith		
Max No Analysis Iterations	0	Time Increment/Critical	160
Output Time Interval	1	Analysis Time-Input (ms)	0
Output Level: Variable vs Time			
Gravity Mass, Pile, Hammer:	32.170	32.170	32.170
Output Segment Generation:	Automatic		

No	Rut=	700.0,	Rtoe =	490.0	kips,	Time	Inc.	=0.078 ms
	mxTForce	mxCForce	mxTStrss	mxCStrss	max V	max D	max Et	
	kips	kips	ksi	ksi	ft/s	inch	kip-ft	
1	0.0	1187.4	0.00	32.17	15.81	1.700	115.81	
2	0.0	1174.4	0.00	31.82	15.78	1.672	115.01	
3	0.0	1176.9	0.00	31.89	15.76	1.644	114.21	
4	0.0	1180.2	0.00	31.98	15.74	1.617	113.41	
5	0.0	1183.2	0.00	32.06	15.72	1.589	112.61	
6	0.0	1186.9	0.00	32.16	15.70	1.561	111.80	
7	0.0	1190.4	0.00	32.25	15.68	1.533	110.98	
8	0.0	1194.3	0.00	32.36	15.65	1.505	110.17	
9	0.0	1198.6	0.00	32.47	15.63	1.478	109.35	
10	-3.7	1202.6	-0.10	32.58	15.58	1.450	108.47	
11	-7.1	1206.6	-0.19	32.69	15.54	1.423	107.42	
12	-9.1	1207.8	-0.25	32.72	15.47	1.396	106.19	
13	-9.7	1208.2	-0.26	32.73	15.41	1.369	104.80	
14	-8.9	1206.5	-0.24	32.69	15.33	1.342	103.23	
15	-6.8	1202.8	-0.18	32.59	15.24	1.316	101.50	
16	-3.4	1198.5	-0.09	32.47	15.14	1.289	99.60	
17	0.0	1212.7	0.00	32.86	15.02	1.263	97.57	
18	0.0	1249.7	0.00	33.86	14.91	1.237	95.43	
19	0.0	1250.4	0.00	33.88	14.76	1.212	93.21	
20	0.0	1211.4	0.00	32.82	14.63	1.188	90.90	
21	0.0	1191.0	0.00	32.27	14.47	1.165	88.51	
22	0.0	1162.3	0.00	31.49	14.33	1.142	86.05	
23	0.0	1140.7	0.00	30.90	14.36	1.121	83.51	
24	0.0	1118.9	0.00	30.32	14.65	1.100	80.91	
25	0.0	1104.1	0.00	29.91	14.72	1.079	78.26	
26	0.0	1161.3	0.00	31.46	13.78	1.060	75.57	
27	0.0	1231.4	0.00	33.36	11.59	1.041	74.03	

(Eq) Strokes Analyzed and Last Return (ft):
 11.20 7.77 7.84

Max. Combustion Pressure 1425.0 psi

No	Rut=	800.0,	Rtoe =	560.0	kips,	Time	Inc.	=0.074 ms
	mxTForce	mxCForce	mxTStrss	mxCStrss	max V	max D	max Et	
	kips	kips	ksi	ksi	ft/s	inch	kip-ft	
1	0.0	1330.3	0.00	36.04	16.38	1.679	119.01	
2	0.0	1295.2	0.00	35.09	16.37	1.644	117.74	
3	0.0	1283.9	0.00	34.79	16.34	1.610	116.48	
4	-0.7	1281.5	-0.02	34.72	16.32	1.577	115.28	
5	-6.6	1274.3	-0.18	34.52	16.30	1.544	114.12	
6	-12.5	1278.6	-0.34	34.64	16.28	1.511	112.98	
7	-18.1	1282.4	-0.49	34.75	16.26	1.479	111.85	
8	-23.5	1287.9	-0.64	34.89	16.23	1.447	110.71	
9	-29.0	1289.1	-0.79	34.92	16.19	1.414	109.55	
10	-34.6	1284.4	-0.94	34.80	16.15	1.381	108.29	
11	-40.2	1274.9	-1.09	34.54	16.10	1.348	106.83	
12	-44.5	1264.1	-1.21	34.25	16.03	1.316	105.18	
13	-47.2	1253.9	-1.28	33.97	15.95	1.284	103.37	
14	-48.1	1246.6	-1.30	33.78	15.86	1.253	101.42	
15	-47.4	1242.8	-1.29	33.67	15.76	1.222	99.33	
16	-45.1	1255.7	-1.22	34.02	15.63	1.192	97.10	
17	-40.9	1307.3	-1.11	35.42	15.51	1.162	94.74	
18	-34.9	1346.2	-0.95	36.47	15.37	1.131	92.23	
19	-27.1	1349.8	-0.73	36.57	15.20	1.101	89.58	
20	-17.5	1312.2	-0.47	35.55	15.02	1.071	86.83	
21	-6.3	1276.7	-0.17	34.59	14.84	1.042	84.05	
22	0.0	1242.0	0.00	33.65	14.68	1.015	81.28	
23	0.0	1216.2	0.00	32.95	14.65	0.989	78.48	
24	0.0	1189.9	0.00	32.24	14.86	0.964	75.68	
25	0.0	1182.5	0.00	32.04	14.80	0.941	72.88	
26	0.0	1238.0	0.00	33.54	13.65	0.918	70.09	
27	0.0	1304.5	0.00	35.34	11.15	0.897	68.46	

(Eq) Strokes Analyzed and Last Return (ft):
 11.20 8.13 8.13
 Max. Combustion Pressure 1425.0 psi

No	Rut= 900.0, Rtoe = 630.0	kips, Time Inc. =0.069 ms	max Et				
	mxTForce kips	mxCForce kips	mxTStrss ksi	mxCStrss ksi	max V ft/s	max D inch	max Et kip-ft
1	0.0	1449.0	0.00	39.26	16.92	1.670	122.35
2	-7.2	1417.6	-0.19	38.41	16.90	1.631	120.71
3	-14.4	1393.5	-0.39	37.75	16.87	1.592	119.02
4	-21.6	1390.8	-0.58	37.68	16.85	1.553	117.32
5	-28.8	1381.0	-0.78	37.42	16.83	1.514	115.66
6	-35.7	1385.2	-0.97	37.53	16.81	1.476	114.10
7	-43.2	1390.7	-1.17	37.68	16.79	1.439	112.60
8	-51.6	1400.1	-1.40	37.93	16.76	1.403	111.13
9	-59.6	1402.9	-1.62	38.01	16.72	1.366	109.66
10	-67.8	1397.8	-1.84	37.87	16.67	1.330	108.06
11	-74.7	1385.4	-2.03	37.54	16.61	1.293	106.24
12	-79.9	1370.8	-2.16	37.14	16.53	1.256	104.17
13	-83.6	1357.5	-2.26	36.78	16.44	1.219	101.91
14	-85.4	1345.6	-2.31	36.46	16.34	1.182	99.49
15	-85.3	1335.5	-2.31	36.18	16.23	1.147	96.96
16	-83.4	1335.9	-2.26	36.19	16.09	1.113	94.34
17	-79.7	1387.5	-2.16	37.59	15.94	1.079	91.62
18	-74.0	1427.6	-2.01	38.68	15.78	1.046	88.80
19	-66.4	1433.6	-1.80	38.84	15.59	1.012	85.86
20	-56.7	1398.5	-1.54	37.89	15.38	0.979	82.79
21	-45.1	1351.0	-1.22	36.60	15.16	0.945	79.61
22	-31.4	1314.6	-0.85	35.62	14.96	0.912	76.36
23	-15.6	1282.0	-0.42	34.73	14.89	0.880	73.20
24	0.0	1252.0	0.00	33.92	15.02	0.851	70.14
25	0.0	1246.8	0.00	33.78	14.83	0.824	67.15
26	0.0	1299.6	0.00	35.21	13.46	0.798	64.26
27	0.0	1359.6	0.00	36.84	10.72	0.774	62.53

(Eq) Strokes Analyzed and Last Return (ft):
 11.20 8.48 8.43

Max. Combustion Pressure 1425.0 psi

No	Rut= 1030.0, Rtoe = 721.0	kips, Time Inc. =0.063 ms	max Et				
	mxTForce kips	mxCForce kips	mxTStrss ksi	mxCStrss ksi	max V ft/s	max D inch	max Et kip-ft
1	0.0	1573.0	0.00	42.62	17.54	1.667	126.50
2	-12.7	1549.6	-0.34	41.98	17.52	1.623	124.43
3	-25.0	1516.7	-0.68	41.09	17.49	1.579	122.28
4	-36.7	1508.1	-0.99	40.86	17.47	1.534	120.05
5	-47.7	1498.5	-1.29	40.60	17.45	1.489	117.79
6	-58.0	1500.9	-1.57	40.66	17.43	1.445	115.57
7	-68.0	1509.1	-1.84	40.89	17.41	1.402	113.49
8	-77.7	1522.3	-2.10	41.24	17.37	1.360	111.51
9	-87.3	1526.8	-2.37	41.37	17.33	1.318	109.59
10	-97.1	1521.7	-2.63	41.23	17.28	1.277	107.57
11	-105.7	1505.9	-2.86	40.80	17.21	1.235	105.30
12	-112.2	1487.8	-3.04	40.31	17.13	1.194	102.75
13	-116.7	1470.5	-3.16	39.84	17.02	1.152	99.95
14	-119.1	1455.6	-3.23	39.44	16.89	1.110	96.94
15	-120.0	1443.8	-3.25	39.12	16.76	1.069	93.80
16	-119.2	1435.1	-3.23	38.88	16.61	1.029	90.59
17	-116.3	1473.9	-3.15	39.93	16.43	0.990	87.35
18	-111.4	1514.5	-3.02	41.03	16.23	0.953	84.07
19	-104.2	1523.8	-2.82	41.28	16.00	0.916	80.74
20	-94.8	1493.3	-2.57	40.46	15.76	0.879	77.31
21	-83.4	1435.7	-2.26	38.90	15.51	0.842	73.77
22	-69.8	1396.4	-1.89	37.83	15.27	0.804	70.12
23	-53.9	1355.4	-1.46	36.72	15.13	0.766	66.42
24	-35.7	1321.3	-0.97	35.80	15.17	0.730	62.84
25	-15.4	1311.1	-0.42	35.52	14.82	0.697	59.55
26	0.0	1360.8	0.00	36.87	13.18	0.667	56.47
27	0.0	1412.9	0.00	38.28	10.14	0.639	54.58

(Eq) Strokes Analyzed and Last Return (ft):
 11.20 8.90 8.85

Max. Combustion Pressure 1425.0 psi

No	Rut= 1130.0, Rtoe = 791.0 kips, Time Inc. =0.058 ms	mxTForce kips	mxCForce kips	mxTStrss ksi	mxCStrss ksi	max V ft/s	max D inch	max Et kip-ft
1	0.0	1652.0	0.00	44.76	18.05	1.671	130.17	
2	-14.1	1636.0	-0.38	44.33	18.02	1.624	127.75	
3	-27.8	1603.5	-0.75	43.44	17.99	1.577	125.27	
4	-40.7	1586.1	-1.10	42.97	17.97	1.529	122.69	
5	-53.1	1578.2	-1.44	42.76	17.95	1.480	120.03	
6	-65.0	1577.6	-1.76	42.74	17.93	1.431	117.34	
7	-77.0	1588.6	-2.09	43.04	17.91	1.383	114.76	
8	-88.7	1603.0	-2.40	43.43	17.88	1.337	112.35	
9	-100.4	1610.2	-2.72	43.63	17.83	1.292	110.05	
10	-111.5	1605.1	-3.02	43.49	17.77	1.247	107.68	
11	-120.6	1587.1	-3.27	43.00	17.69	1.203	105.07	
12	-127.3	1566.1	-3.45	42.43	17.60	1.158	102.16	
13	-134.3	1546.1	-3.64	41.89	17.48	1.113	98.96	
14	-138.4	1529.4	-3.75	41.44	17.35	1.068	95.52	
15	-140.4	1516.4	-3.80	41.08	17.20	1.023	91.92	
16	-139.9	1507.0	-3.79	40.83	17.01	0.979	88.25	
17	-137.3	1533.4	-3.72	41.54	16.82	0.937	84.57	
18	-132.7	1573.8	-3.59	42.64	16.59	0.896	80.90	
19	-125.5	1584.1	-3.40	42.92	16.34	0.856	77.22	
20	-116.0	1557.2	-3.14	42.19	16.08	0.816	73.50	
21	-104.7	1501.4	-2.84	40.68	15.79	0.777	69.70	
22	-91.6	1453.1	-2.48	39.37	15.53	0.737	65.80	
23	-76.3	1407.0	-2.07	38.12	15.34	0.696	61.82	
24	-58.4	1370.7	-1.58	37.14	15.31	0.655	57.86	
25	-37.9	1355.2	-1.03	36.72	14.84	0.618	54.19	
26	-14.8	1403.4	-0.40	38.02	12.97	0.584	50.94	
27	0.0	1451.5	0.00	39.33	9.77	0.553	48.91	

(Eq) Strokes Analyzed and Last Return (ft):
 11.20 9.23 9.16

Max. Combustion Pressure 1425.0 psi

No	Rut= 1200.0, Rtoe = 840.0 kips, Time Inc. =0.056 ms	mxTForce kips	mxCForce kips	mxTStrss ksi	mxCStrss ksi	max V ft/s	max D inch	max Et kip-ft
1	0.0	1695.8	0.00	45.94	18.32	1.671	132.05	
2	-15.6	1684.4	-0.42	45.64	18.29	1.622	129.39	
3	-30.8	1655.5	-0.84	44.85	18.27	1.573	126.69	
4	-45.8	1632.1	-1.24	44.22	18.24	1.523	123.88	
5	-60.2	1624.4	-1.63	44.01	18.23	1.472	120.97	
6	-74.5	1622.5	-2.02	43.96	18.20	1.421	117.99	
7	-88.4	1635.0	-2.39	44.30	18.18	1.370	115.08	
8	-102.0	1650.1	-2.76	44.71	18.14	1.321	112.36	
9	-115.2	1659.2	-3.12	44.95	18.10	1.273	109.79	
10	-127.8	1653.8	-3.46	44.81	18.03	1.226	107.18	
11	-138.2	1635.2	-3.74	44.30	17.96	1.180	104.33	
12	-145.9	1611.8	-3.95	43.67	17.85	1.133	101.17	
13	-150.3	1590.3	-4.07	43.09	17.73	1.086	97.72	
14	-151.5	1572.6	-4.11	42.61	17.59	1.039	94.01	
15	-151.9	1558.8	-4.11	42.23	17.42	0.992	90.12	
16	-153.1	1549.1	-4.15	41.97	17.24	0.945	86.13	
17	-151.4	1567.6	-4.10	42.47	17.01	0.900	82.15	
18	-146.8	1607.4	-3.98	43.55	16.77	0.857	78.20	
19	-140.0	1617.1	-3.79	43.81	16.51	0.815	74.29	
20	-130.3	1593.0	-3.53	43.16	16.22	0.774	70.38	
21	-118.2	1541.0	-3.20	41.75	15.93	0.733	66.40	
22	-104.2	1485.4	-2.82	40.24	15.63	0.691	62.34	
23	-88.3	1437.3	-2.39	38.94	15.42	0.649	58.21	
24	-69.7	1399.7	-1.89	37.92	15.34	0.607	54.09	
25	-48.7	1377.8	-1.32	37.33	14.78	0.566	50.16	
26	-24.8	1424.9	-0.67	38.60	12.78	0.529	46.75	
27	0.0	1470.2	0.00	39.83	9.48	0.496	44.61	

(Eq) Strokes Analyzed and Last Return (ft):
 11.20 9.43 9.37

Max. Combustion Pressure 1425.0 psi

No	Rut= 1300.0, Rtoe = 910.0	kips, Time Inc. =0.052 ms	max Et				
	mxTForce kips	mxCForce kips	mxTStrss ksi	mxCStrss ksi	max V ft/s	max D inch	
1	0.0	1755.1	0.00	47.55	18.81	1.680	135.90
2	-18.2	1748.8	-0.49	47.38	18.77	1.628	132.87
3	-35.1	1726.2	-0.95	46.77	18.75	1.576	129.82
4	-51.5	1698.2	-1.40	46.01	18.73	1.523	126.69
5	-68.8	1687.4	-1.86	45.72	18.70	1.469	123.42
6	-85.1	1686.5	-2.31	45.69	18.68	1.415	120.05
7	-100.9	1698.4	-2.73	46.01	18.66	1.360	116.70
8	-116.8	1715.4	-3.16	46.47	18.63	1.307	113.54
9	-132.4	1725.6	-3.59	46.75	18.57	1.256	110.58
10	-147.4	1719.9	-3.99	46.60	18.51	1.206	107.62
11	-159.7	1700.1	-4.33	46.06	18.42	1.157	104.42
12	-168.2	1674.6	-4.56	45.37	18.31	1.107	100.90
13	-173.3	1651.2	-4.70	44.74	18.17	1.058	97.08
14	-175.6	1631.4	-4.76	44.20	18.01	1.008	92.97
15	-174.8	1616.9	-4.74	43.81	17.83	0.958	88.65
16	-171.2	1607.2	-4.64	43.54	17.62	0.908	84.23
17	-164.9	1617.8	-4.47	43.83	17.39	0.860	79.81
18	-161.7	1656.5	-4.38	44.88	17.12	0.814	75.46
19	-155.5	1664.8	-4.21	45.11	16.82	0.769	71.19
20	-146.0	1643.9	-3.95	44.54	16.52	0.726	66.94
21	-133.4	1597.9	-3.61	43.29	16.20	0.682	62.69
22	-118.7	1533.3	-3.21	41.54	15.87	0.638	58.37
23	-101.6	1484.1	-2.75	40.21	15.62	0.594	54.00
24	-82.5	1443.2	-2.24	39.10	15.46	0.549	49.63
25	-60.4	1418.6	-1.64	38.43	14.77	0.505	45.42
26	-34.8	1461.7	-0.94	39.60	12.58	0.464	41.72
27	-6.0	1503.4	-0.16	40.73	9.15	0.428	39.39

(Eq) Strokes Analyzed and Last Return (ft):
 11.20 9.77 9.68

Max. Combustion Pressure 1425.0 psi

No	Rut= 1400.0, Rtoe = 980.0	kips, Time Inc. =0.049 ms	max Et				
	mxTForce kips	mxCForce kips	mxTStrss ksi	mxCStrss ksi	max V ft/s	max D inch	
1	0.0	1802.0	0.00	48.82	19.21	1.685	139.00
2	-20.5	1798.5	-0.55	48.73	19.18	1.631	135.65
3	-39.6	1782.7	-1.07	48.30	19.15	1.576	132.29
4	-57.7	1756.1	-1.56	47.58	19.13	1.521	128.85
5	-75.7	1737.7	-2.05	47.08	19.11	1.465	125.27
6	-93.6	1738.3	-2.54	47.10	19.09	1.407	121.55
7	-110.8	1749.3	-3.00	47.39	19.06	1.350	117.82
8	-128.5	1769.2	-3.48	47.93	19.03	1.294	114.27
9	-145.9	1780.0	-3.95	48.23	18.98	1.240	110.98
10	-162.5	1774.8	-4.40	48.08	18.90	1.188	107.69
11	-175.8	1752.3	-4.76	47.47	18.80	1.135	104.16
12	-185.5	1724.4	-5.02	46.72	18.68	1.084	100.30
13	-191.9	1700.6	-5.20	46.07	18.54	1.031	96.11
14	-194.6	1682.1	-5.27	45.57	18.37	0.979	91.61
15	-194.2	1667.1	-5.26	45.17	18.16	0.926	86.89
16	-190.4	1657.7	-5.16	44.91	17.93	0.874	82.05
17	-182.7	1661.1	-4.95	45.01	17.67	0.823	77.23
18	-173.7	1697.8	-4.71	46.00	17.38	0.775	72.51
19	-166.9	1702.9	-4.52	46.14	17.07	0.727	67.89
20	-157.4	1682.6	-4.27	45.59	16.73	0.681	63.33
21	-143.9	1642.5	-3.90	44.50	16.38	0.636	58.80
22	-128.3	1576.4	-3.48	42.71	16.02	0.590	54.24
23	-110.8	1523.6	-3.00	41.28	15.73	0.543	49.64
24	-90.4	1479.1	-2.45	40.07	15.50	0.496	45.07
25	-67.4	1454.1	-1.83	39.40	14.68	0.449	40.64
26	-40.3	1490.0	-1.09	40.37	12.34	0.405	36.69
27	-9.1	1527.8	-0.25	41.39	8.82	0.366	34.16

(Eq) Strokes Analyzed and Last Return (ft):
 11.20 10.05 9.96

Max. Combustion Pressure 1425.0 psi

No	Rut= 1500.0, Rtoe = 1050.0	kips, Time Inc. =0.047 ms	max Et				
	mxTForce kips	mxCForce kips	mxTStrss ksi	mxCStrss ksi	max V ft/s	max D inch	
1	0.0	1839.0	0.00	49.82	19.54	1.688	141.48
2	-21.1	1835.6	-0.57	49.73	19.50	1.631	137.79
3	-41.3	1824.2	-1.12	49.42	19.48	1.574	134.16
4	-61.1	1804.0	-1.66	48.88	19.45	1.517	130.46
5	-79.6	1781.5	-2.16	48.27	19.43	1.459	126.62
6	-98.1	1779.2	-2.66	48.20	19.41	1.403	122.65
7	-115.9	1789.6	-3.14	48.49	19.39	1.346	118.69
8	-134.6	1808.9	-3.65	49.01	19.35	1.286	114.77
9	-153.3	1820.6	-4.15	49.33	19.29	1.226	111.25
10	-171.0	1814.5	-4.63	49.16	19.22	1.172	107.75
11	-185.4	1790.4	-5.02	48.51	19.11	1.118	103.98
12	-196.4	1759.2	-5.32	47.66	18.98	1.064	99.83
13	-203.8	1733.4	-5.52	46.96	18.82	1.010	95.32
14	-207.3	1716.7	-5.62	46.51	18.64	0.955	90.48
15	-207.0	1707.5	-5.61	46.26	18.42	0.901	85.37
16	-203.0	1701.7	-5.50	46.10	18.16	0.846	80.13
17	-195.0	1697.2	-5.28	45.98	17.88	0.792	74.89
18	-184.4	1732.0	-5.00	46.92	17.57	0.741	69.78
19	-174.3	1733.4	-4.72	46.96	17.24	0.691	64.82
20	-164.2	1710.3	-4.45	46.34	16.88	0.643	59.96
21	-149.8	1672.9	-4.06	45.32	16.50	0.595	55.16
22	-132.5	1613.7	-3.59	43.72	16.11	0.548	50.36
23	-113.9	1554.6	-3.09	42.12	15.77	0.499	45.57
24	-92.8	1508.7	-2.51	40.87	15.48	0.450	40.81
25	-68.2	1483.5	-1.85	40.19	14.54	0.401	36.20
26	-39.4	1509.9	-1.07	40.91	12.05	0.354	32.00
27	-6.4	1543.6	-0.17	41.82	8.48	0.312	29.26

(Eq) Strokes Analyzed and Last Return (ft):
 11.20 10.30 10.21

Max. Combustion Pressure 1425.0 psi

No	Rut= 1600.0, Rtoe = 1120.0	kips, Time Inc. =0.044 ms	max Et				
	mxTForce kips	mxCForce kips	mxTStrss ksi	mxCStrss ksi	max V ft/s	max D inch	
1	0.0	1870.2	0.00	50.67	19.83	1.691	143.83
2	-23.3	1865.6	-0.63	50.55	19.79	1.631	139.80
3	-45.0	1853.7	-1.22	50.22	19.77	1.573	135.87
4	-66.4	1838.1	-1.80	49.80	19.74	1.515	131.94
5	-85.9	1820.7	-2.33	49.33	19.72	1.462	128.30
6	-104.1	1816.3	-2.82	49.21	19.70	1.406	124.77
7	-122.0	1824.4	-3.31	49.43	19.67	1.347	120.91
8	-140.2	1843.8	-3.80	49.95	19.63	1.287	116.76
9	-159.7	1854.6	-4.33	50.25	19.58	1.225	112.46
10	-178.2	1848.4	-4.83	50.08	19.49	1.166	108.22
11	-193.2	1821.9	-5.23	49.36	19.38	1.110	104.17
12	-204.7	1787.7	-5.55	48.43	19.24	1.056	99.94
13	-212.7	1759.7	-5.76	47.68	19.08	1.001	95.29
14	-216.8	1742.5	-5.88	47.21	18.87	0.944	90.11
15	-216.7	1734.5	-5.87	46.99	18.64	0.886	84.41
16	-212.1	1733.5	-5.75	46.97	18.36	0.825	78.68
17	-203.4	1733.2	-5.51	46.96	18.06	0.768	73.08
18	-192.2	1761.4	-5.21	47.72	17.72	0.714	67.60
19	-178.7	1759.5	-4.84	47.67	17.37	0.662	62.28
20	-166.6	1732.2	-4.51	46.93	16.99	0.612	57.11
21	-151.7	1692.8	-4.11	45.86	16.58	0.562	52.03
22	-133.3	1636.9	-3.61	44.35	16.15	0.513	47.02
23	-111.4	1583.6	-3.02	42.90	15.77	0.463	42.04
24	-88.6	1534.9	-2.40	41.59	15.42	0.412	37.12
25	-62.8	1509.2	-1.70	40.89	14.36	0.361	32.32
26	-32.6	1524.8	-0.88	41.31	11.75	0.311	27.89
27	0.0	1554.7	0.00	42.12	8.16	0.266	24.88

(Eq) Strokes Analyzed and Last Return (ft):
 11.20 10.51 10.43

Max. Combustion Pressure 1425.0 psi

Flatiron, BR26P2, PP24"x0.50", D100, 90ft, HI
Robert Miner Dynamic Testing, Inc.

12/16/2021
GRLWEAP Version 2010

Rut kips	B1 b/ft	Ct	Stroke down	(ft) up	Ten ksi	Str ksi	i	t	Comp ksi	Str ksi	i	t	ENTHRU kip-ft	B1 b/min	Rt
700.0	13.8		7.77	7.84	-0.26	13	41		33.88		19	10	115.8		41.7
800.0	16.5		8.13	8.13	-1.30	14	39		36.57		19	10	119.0		40.9
900.0	19.9		8.48	8.43	-2.31	14	39		39.26		1	14	122.3		40.1
1030.0	25.6		8.90	8.85	-3.25	15	37		42.62		1	14	126.5		39.2
1130.0	31.3		9.23	9.16	-3.80	15	35		44.76		1	14	130.2		38.6
1200.0	36.8		9.43	9.37	-4.15	16	34		45.94		1	14	132.1		38.1
1300.0	46.5		9.77	9.68	-4.76	14	32		47.55		1	14	135.9		37.5
1400.0	61.2		10.05	9.96	-5.27	14	32		48.82		1	14	139.0		37.0
1500.0	84.5		10.30	10.21	-5.62	14	32		49.82		1	14	141.5		36.6
1600.0	124.7		10.51	10.43	-5.88	14	31		50.67		1	14	143.8		36.2